Beyond Singapore's Mathematics Textbooks

Focused and Flexible Supports for Teaching and Learning

By Patsy Wang-Iverson, Perla Myers, and Edmund Lim W.K.

It has been over 10 years since schools in the United States began looking to Singapore to learn from its approach to mathematics education. This interest can be traced to Singapore students' consistently high performance on all four of the Trends in International Mathematics and Science Studies (TIMSS), which were conducted in 1995, 1999, 2003, and 2007.[1] Even more important, Singapore has been pursuing excellence and equity, having shown in TIMSS 2003 and 2007 a relatively smaller performance gap than the United States among students from differing socioeconomic backgrounds.[2]

As part of TIMSS 1995, a group of researchers conducted an in-depth analysis of curricula from the participating countries.[3] When they summarized the grades 1–8 mathematics scopes and sequences from the six top-performing countries (Singapore, Korea, Japan, Hong Kong, Belgium [Flemish-speaking], and the Czech Republic), their findings revealed a common, coherent curriculum sequence.[4] The coherence, focus, and rigor found in the top-performing countries stood in sharp contrast to the results for the United States. Examining mathematics standards from 21 states, the researchers found too many mathematics topics per grade and characterized the hodgepodge of standards as "a mile wide and an inch deep."[5]

For many educators, researchers, and policymakers, the results ignited great interest in the top-performing countries' mathematics curricula and teaching. Of the six top performers, only Singapore conducts classroom instruction and writes its textbooks in English, a pragmatic decision made at the time of its independence in 1965.

Today, Singapore's mathematics textbooks are available in the United States,* so it is tempting to think that there is an easy solution to increasing mathematics achievement here—just adopt the textbooks.† But the textbooks are not solely responsible for Singapore's success; these written resources are just one part of a multifaceted approach. Singapore's academic strength lies in its national commitment to high-quality education and the overall

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coherence of its educational system. Singapore's goals for its students are fully supported by a systematic plan that includes a realistic timeline and ample funding. The investment in education is all-encompassing—it includes all levels of the education community, from the schools, to the National Institute of Education (Singapore's sole teacher-training institution) to the Ministry of Education (MOE). Singapore's commitment to education—which is derived from its ongoing desire to improve by learning from the strengths of other countries—begins with a first-class curriculum *and* the nurturing of educators at all levels.

Singapore's national mathematics syllabus provides the foundation for teaching and learning mathematics. The syllabus is comprehensive, yet concise and coherent. Curriculum, teaching, learning, and assessments (both school-based and national) are closely aligned with the syllabus, and are regularly reviewed and updated to ensure that they remain relevant to the needs and interests of students and teachers.

Having a cogent curriculum and well-written textbooks can improve instruction to a certain extent. At the same time, preparing, hiring, nurturing, and retaining knowledgeable, caring, and skilled educators are essential to successful learning and teaching in the classroom. In particular, Singapore's pre-service teacher-education programs play a vital role in Singapore's success in education. Unlike in the United States, prospective teachers, who are selected from among the top one-third of high school graduates, receive free tuition and a stipend during their teacher preparation program. Once they become teachers, they receive competitive pay and support throughout their careers.

In this paper, we explore the preparation and support of mathematics teachers in Singapore. Explaining the entire teacher-preparation program is beyond what we can accomplish in a single article. Instead, we have chosen to take a careful look at two ways in which teacher preparation and support are dramatically different in Singapore and the United States: the flexibility in pathways and the focus on goals.

Singapore's educational system—from primary school through teacher preparation and support—is characterized by flexibility. In particular, Singapore offers high performers various opportunities to become teachers. Formal teacher preparation can begin at different stages: right after students complete post-secondary school (equivalent to the end of 12th grade in the United States), after completion of a university degree, or as a midcareer change.

At the same time, Singapore's whole educational system—including its teacher preparation and support—is focused on the goal of having all students master the national curriculum. Teachers are encouraged to teach as they see fit, but the content and skills that students must master in each subject and at each grade are clearly specified in the national curriculum; they are also well reinforced through the approved textbooks, aligned assessments, and carefully constructed teacher preparation and professional development.

Assuming most readers are not well acquainted with Singapore's education system, and believing teacher preparation (just like preparation for any other career) formally begins when children start school, let us start with a brief look at how flexibility and focus play out in the primary and secondary schools. We will begin with the focus provided by the national curriculum.

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I. A Focused National Curriculum

Singapore's primary (grades 1–6) and secondary (grades 7–10) schools follow the national curriculum[‡] developed by the Curriculum Planning and Development Division of the MOE. In mathematics, a pentagonal framework designed to develop students' problem-solving abilities sets the direction for learning, teaching, and assessment. The syllabus provides details that guide teachers in planning, preparing, and implementing mathematics programs in their schools. Teachers are encouraged to be flexible and creative in implementing the syllabus in the classroom, but they must be careful to maintain its scope and sequence so as to prepare students for high-stakes national exams at the end of primary and secondary school. (See the sidebar on page 32 for a description of the framework and an excerpt from the syllabus.)

Textbooks in Singapore closely follow the national syllabus. Until 2001, they were written by a unit of the MOE. Now textbooks and activity books are developed by private publishers, subject to MOE approval. In mathematics, the majority of primary schools in Singapore currently use either the *My Pals Are Here* series or the *Shaping Mathematics* series. An extraordinary amount of thought has gone into these slim and focused textbooks. They present the mathematics content in a way that helps students grasp the concepts, yet they are slim enough that teachers can provide additional lessons on topics, as needed, without pressure to "cover" an excessive amount of material. Furthermore, they are written in simple English to accommodate the more than 40 percent[§] of Singapore students who most frequently speak a language other than English at home.

*The Singapore textbook series used most commonly in the United States at present is *Primary Mathematics* (grades 1–6), U.S. edition, published in 2003 and based on the 1983 curriculum framework (see www.singaporemath.com). Notably, these books have been integrated into some courses for pre-service American teachers. The college textbooks *Elementary Mathematics for Teachers*[6] and *Elementary Geometry for Teachers*[7] incorporate the U.S. edition of *Primary Mathematics* and Singapore's *New Elementary Mathematics 1* for supplementary reading and homework assignments. Another pre-service mathematics textbook, *Mathematics for Elementary Teachers*,[8] also was influenced (especially chapters 3, 7, and 13) by the *Primary Mathematics* series.

†Some states have approved modified versions of Singapore textbooks that do not preserve Singapore's concise and coherent curriculum. For example, in the California version, variables, which are not taught until grade 7 in Singapore, are introduced in grade 5. *Math in Focus*, a U.S. version of a Singapore mathematics textbook series, *My Pals Are Here*, has been approved for use in Indiana, Kentucky, and Oklahoma.

‡International and private schools are not bound by the national syllabi.

§When the curriculum was developed in the early 1980s, 77 percent of Singapore's students did not speak English at home.

The clarity and detail of the curriculum offer many benefits. For example, when teachers develop lesson plans either individually or in a group, since *what* will be taught is already determined, teachers can focus on *how* to teach it. Teachers are then able to make sure the content for each grade is clear to the students, and they can provide students with the support needed to stay at grade level. Consistency of content also helps with student mobility—if students change schools, they do not fall behind or end up with gaps in their learning. Additionally, teacher preparation and professional development can be more effective since they are based on the content teachers are expected to teach.

II. A Flexible Educational Structure

Singapore's educational system is notable for its flexibility and efforts to accommodate the needs of individual students. The MOE acknowledges that people are different—they have different abilities, interests, and motivations; they require different support systems; and they develop at different rates. Singapore provides flexibility throughout the educational system in order to accommodate its different learners while maintaining a firm commitment to each student mastering the core content in the curriculum. Some examples of how Singapore achieves quality through flexibility follow.

Student support begins in grade 1 for students with inadequate prior academic exposure. The goal is to have them at grade level when they enter grade 2.

1) *Different tracks lead to the same end goal in primary school.* A Singapore education for most students begins with two years of private kindergarten, followed by six years of primary school (elementary school) in the national education system. Schools provide differentiated learning experiences for students with different needs. Student support begins in grade 1 with a learning support system for students with inadequate prior academic exposure. They are placed in small classes of up to 12 students, and the goal is to have them at grade level when they enter grade 2. Starting in grade 4, students are separated according to their performance in specific subjects such as mathematics and their mother tongue language (Mandarin, Malay, or Tamil). Lessons in each track are conducted at different rates of speed and levels of difficulty in order to accommodate the abilities of the students and to optimize their learning potential. As in the United States, tracking students engenders ongoing debate. Yet, it allows teachers to proceed at a pace and depth suitable for each group of students. Slower children receive extra instruction to help them achieve the high standards set by the national curriculum. Since Singapore's educational goals are clear, the system is able to achieve high quality while providing flexibility. At the end of the sixth year of primary school, students in the national school system take high-stakes national examinations, called the Primary School Leaving Examinations (PSLE), in English, mathematics, science, and their mother tongue language.*

2) *Paths have different lengths, but the same core content, in secondary school.* Based on their performance on the PSLE overall and in each subject, students follow one of three secondary education paths† beginning in grade 7:

i) four years in the Normal (Technical) course,
ii) four years in the Express course, or
iii) five years in the Normal (Academic) course.

The less academically inclined students (about 12 percent of the population) are assigned to the Normal (Technical) stream. Although their curriculum is less demanding academically than that of the other streams, they learn the core content set forth in the national curriculum. In mathematics, that includes topics such as graphs of quadratic functions and their properties, rotational symmetry, and the volume and surface area of pyramids, cones, and spheres.[9]

The curricula for students in the Express and Normal (Academic) streams are similar to each other, with the main difference being that Express students (about 64 percent of the population) complete their course of study in four years while the curriculum for the Normal (Academic) students (about 22 percent of the population) is spread over five years.[10]

3) *Students have opportunities to move between paths.* Once students are placed along a certain path, they have several opportunities to move to a different path based on their performance. For instance, if a child in primary school shows more growth and readiness in a certain subject, he or she may be moved to a higher achievement track in that subject. Also, Normal (Technical) stream students who excel in the first or second year of secondary school can be transferred to the Normal (Academic) stream. Similarly, students who do very well in the Normal (Academic) stream in the first or second year can transfer to the Express stream. Conversely, students in the Express stream who perform poorly may be transferred to the Normal (Academic) stream.

4) *Students take different paths after secondary school.* After successful completion of secondary school (which is the equivalent of 10th grade in the United States), there are various educational routes for graduates. Further education is not mandatory, but the vast majority of students continue their education. The academic options are plentiful, ranging from vocational and industry-related courses offered by the Institute of Technical Education[11] to university-preparatory courses offered by two-year junior colleges. Importantly, all of the options leave open the door to a

*Severely retarded children are usually educated in special schools and do not take the PSLE. Students with learning difficulties (e.g., dyslexia or ADHD) or hearing impairments are mainstreamed and take the PSLE, though a minority may be exempted from certain subjects. The bottom range of students (about 15 percent) may take a different version of the PSLE, a Foundation PSLE, in certain subjects, and the regular PSLE in other subjects.

†Based on the 2007 PSLE results, 98 percent of students qualified for mainstream secondary-school education. The remaining 2 percent were considered not ready for mainstream secondary schools and better suited for the two secondary schools that provide vocational training. These students can still progress on to vocational higher education if they perform well.

university education. Students who complete the Normal (Technical) course in secondary school and then attend the Institute of Technical Education could, if they perform well, go to a polytechnic institute (which offers a mix of academic and industry-related courses) and then a university. This route is several years longer than the fastest route (which entails studying in the Express stream, attending a junior college, and then going to a university), but for some students, that slower pace is exactly what they need. Unlike in the United States, however, there are no nonselective universities. At each juncture, students must perform well on rigorous exams in order to proceed to the next institution.

III. Flexibility and Focus in Teacher Preparation

Flexibility and focus also are key characteristics of Singapore's approach to teacher preparation. Teachers[†] at public and government-aided schools undergo teacher preparation, education, and certification at the National Institute of Education (NIE), the sole provider of the country's teacher education. Although there are various degree programs that prospective (and in-service) teachers can pursue, there is also tight quality control since all teacher preparation is overseen by the MOE and delivered by the NIE, and exactly what teachers must accomplish is specified by the national curriculum.

Primary school teacher candidates may be offered or assigned one of several program options. They may pursue a two-year Diploma in Education[§] or a four-year Bachelor of Arts in education or Bachelor of Science in education. Candidates who already have a university degree in another field can earn a one-year Post Graduate Diploma in Education. As in the United States, most lower-grade primary school teachers are generalists who teach English, mathematics, science, and social studies. However, some teachers in the upper elementary grades specialize in teaching mathematics.

Secondary school teachers usually are content specialists. Mathematics teacher candidates may pursue a humanities-based bachelor's degree in education by specializing in mathematics and one liberal arts subject,** or a science-based degree by specializing in mathematics, a liberal art, and one or two science subjects. Those who already hold a university degree have to earn a Post Graduate Diploma in Education for primary and secondary school teachers.

[†]There are a small number of teachers from other countries who have not attended the NIE.

[§]As recently as 1993, the Diploma in Education was the highest level of education attained by most primary school teachers. The MOE's goal is for all teachers to eventually pursue a minimum of a bachelor's degree. This goal comes with financial incentives, as there is a significant difference between the starting salaries of the teachers who have a bachelor's degree and of those who do not. A number of teachers with a Diploma in Education have gone back to the NIE to study for another two years to earn a Bachelor of Education degree.

**Options include art, drama, English language, English literature, geography, history, Malay language, and music.

Recruitment of Teacher Candidates

The teaching profession is highly respected and well compensated in Singapore, and teacher quality is a top priority. This serious commitment to education is reflected in the financial support[††] provided to attract, retain, and develop high-quality candidates.[12] More than 95 percent of the students accepted by the NIE simultaneously become contracted employees of the MOE; the MOE pays their tuition and provides a monthly stipend. As teachers (in public or government-aided schools), they are employees of the MOE, so beginning teacher preparation is very much like beginning work. In exchange for this financial support, teachers must commit to teaching at a school selected by the MOE for three to six years, depending on the degree program. If they do not fulfill their obligation, whether they choose to leave or are deemed inadequate, they must repay the money with interest.

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Candidates for teacher-education programs are selected from the top one-third of each graduating cohort from universities, polytechnics, junior colleges, and the Millennia Institute (which offers the same pre-university curriculum as the junior colleges, but at a slower pace).[‡‡] As a result, teacher candidates begin their teacher training with a solid foundation in mathematics and all other subjects covered by the national curriculum. But entrance is not based exclusively on academic achievement. Candidates also are interviewed by NIE academic staff and MOE staff to determine their suitability to work with children and youth. For individuals making a transition from another career to teaching, prior work experience is also taken into consideration.

Pre-Service Programs

The objective of the pre-service program is to help individuals begin their journey to become reflective teachers with an evidence-based practice. As such, teacher preparation in mathematics ensures teachers have six key characteristics: (1) mathematical knowledge (e.g., school-related mathematics content and mathematical reasoning); (2) knowledge of curriculum (e.g., lesson plans aligned with recent reforms); (3) knowledge of pupils (e.g., their common errors and misconceptions, as well as their abilities

[††]Teachers' starting salaries, which depend on if they have a degree, a degree with merit, an honors degree, and/or relevant work experience, are quite attractive. Their salaries are comparable to the starting salaries of professionals such as engineers.

[‡‡]In the past, most teachers came from the Express stream and completed a junior college education. Now, a small number of teachers come from the polytechnics.

and interests); (4) mathematics-based pedagogy (e.g., effective questioning and discussion, and classroom management); (5) knowledge of assessment (e.g., various types of formative and summative assessments); and (6) lifelong learning and values (e.g., professional development and professional communities).

Since the national curriculum is clearly defined, teacher candidates can study the content that they will be responsible for teaching in depth and from different viewpoints. Quite purposefully, NIE academic staff members have varied backgrounds. The mathematics department includes both mathematicians and mathematics educators specializing in different fields: mathematics content, teaching and learning mathematics, or curriculum and pedagogy. There are also experienced mathematics schoolteachers (usually former mathematics department heads) as well as former MOE mathematics curriculum officers who work with teacher candidates. Selected mathematics classroom teachers can spend up to four years as staff at the NIE and may conduct postgraduate research while they teach, guide, and mentor teacher candidates.

NIE teacher candidates take a range of core and elective courses. For instance, teacher candidates in the four-year Bachelor of Arts (BA) in education or Bachelor of Science (BSc) in education programs take courses in education studies, curriculum studies, and subject knowledge, as well as other courses and practica (in which they are assigned to schools).

In the first year, BA/BSc candidates for teaching in the primary grades

Shared Structure, Common Content

In Singapore, the foundation for learning, teaching, and assessing mathematics is a pentagonal framework that shows how the following five interrelated components are all essential to developing students' ability to solve problems (including nonroutine, open-ended, and real-world problems):*

1. *Concepts*: Students must attain conceptual understanding of mathematical concepts—numerical, algebraic, geometrical, statistical, probabilistic, and analytical—in order to learn mathematics successfully. Conceptual understanding allows students to see mathematical ideas as interconnected, apply mathematics in various contexts, develop mathematical proficiency, and gain confidence in their abilities and appreciation for mathematics.
2. *Skills*: Students must develop procedural skills that are needed for problem solving—numerical written and mental calculation, algebraic manipulation, spatial visualization, data analysis, measurement, use of mathematical tools and technology, and estimation. Students should master these skills, but they should do so mindfully—with conceptual understanding of the procedures.
3. *Processes*: Students must combine the knowledge and skills that are necessary to learning and applying mathematical concepts—mathematical reasoning, communication, making connections, thinking skills and strategies, and application and modeling.
4. *Attitudes*: Students' attitudes in mathematics include their beliefs about mathematics and its usefulness, their interest and enjoyment in learning mathematics, their appreciation of the beauty and power of mathematics, their confidence in using mathematics, and their perseverance in solving a problem. Since attitudes are shaped by learning experiences, teachers are encouraged to create positive learning experiences that children of all abilities will find challenging and rewarding.
5. *Metacognition*: Students should be able to monitor and control their thinking in order to progress as problem solvers. They should be able to analyze the selection of particular strategies for learning or for problem solving, and understand why certain methods are unsuccessful.

*To read more about the pentagonal framework, see Lee Peng Yee and Lee Ngan Hoe, eds., *Teaching Primary School Mathematics: A Resource Book*, 2nd ed. (Singapore: McGraw-Hill, 2009).

According to Singapore's mathematics syllabus,† the primary purpose of the framework is to explain "the philosophy of the syllabus and the spirit in which it should be implemented." That done, the portion of the syllabus devoted to grade-by-grade content is concise, coherent, and uncluttered. As an example, here is the *complete* mathematics syllabus for primary 1 (first grade). Compared with most standards in the United States, it has clear content and is a reasonable length.

–P.W.I., P.M., E.L.W.K.

1. Whole Numbers

Numbers up to 100

Include:

- counting to tell the number of objects in a given set,
- comparing the number of objects in two or more sets,
- use of ordinal numbers (first, second, up to tenth) and symbols (1st, 2nd, 3rd, etc.),
- number notation and place values (tens, ones),
- reading and writing numbers in numerals and in words,
- comparing and ordering numbers,
- number patterns.

Exclude:

- use of the terms 'cardinal number' and 'ordinal number',
- use of the symbols > and <.

Addition and subtraction

Include:

- concepts of addition and subtraction,
- use of the addition symbol (+) or subtraction symbol (–) to write a mathematical statement for a given situation,
- comparing two numbers within 20 to tell how much one number is greater (or smaller) than the other,
- recognising the relationship between

†The mathematics syllabus is separated into primary and secondary levels; both include the framework. See **www.moe.gov.sg/education/syllabuses/sciences**.

enroll in basic courses, including three education courses such as educational psychology, critical perspectives on education, and information and communication technology. In the second year, they take mathematics courses, including numbers and operations, and fundamental principles of primary mathematics, as well as a curriculum course that provides an overview of the Singapore Primary Mathematics Curriculum. Teacher candidates also learn how to prepare lesson plans, which include teaching objectives, learning outcomes, teaching and learning processes, and resources. They explore pedagogical strategies and psychological theories related to mathematics education and how to teach topics such as whole numbers, fractions, decimals, percentages, ratios, direct proportion, rate, and speed.

In the third year, BA/BSc teacher candidates enroll in a more advanced curriculum course, along with two more subject-knowledge courses in which they learn about teaching problem solving, conducting mathematical investigations, and facilitating mathematical communication. In addition, they learn how to teach algebra, geometry and measurement, data analysis, and statistics. Throughout the curriculum courses, while covering the various topics, teacher candidates explore the use of technology and the common errors made by primary school students.

In the fourth and final year, BA/BSc teacher candidates take another mathematics curriculum course, in which they learn about various traditional assessment strategies, including details about planning and constructing test items. Another major area of study is the practice of teaching skills, which includes catering to students of mixed abilities. BA/BSc teacher candidates who wish to teach upper primary mathematics* may take additional courses on pedagogical skills and content knowledge, as well as advanced use of technology, and challenging problems and games.

*Teachers who do not take these optional courses may still be assigned to teach upper primary levels. Similarly, teacher candidates who take the optional courses may be assigned to teach lower primary classes if there is a need.

addition and subtraction,
- building up the addition bonds up to 9 + 9 and committing to memory,
- solving 1-step word problems involving addition and subtraction within 20,
- addition of more than two 1-digit numbers,
- addition and subtraction within 100 involving
  - a 2-digit number and ones,
  - a 2-digit number and tens,
  - two 2-digit numbers,
- addition and subtraction using formal algorithms.

Mental calculation
Include:
- addition and subtraction within 20,
- addition and subtraction involving
  - a 2-digit number and ones without renaming,
  - a 2-digit number and tens.

Multiplication and division
Include:
- multiplication as repeated addition (within 40),
- use of the multiplication symbol (×) to write a mathematical statement for a given situation,
- division of a quantity (not greater than 20) into equal sets:
  - given the number of objects in each set,
  - given the number of sets,
- solving 1-step word problems with pictorial representation.

Exclude:
- use of multiplication tables,
- use of the division symbol (÷).

2. Measurement

Length and mass
Include:
- measurement and comparison of the lengths/masses of two or more objects in non-standard units,
- use of the following terms:
  long, longer, longest
  short, shorter, shortest
  tall, taller, tallest
  high, higher, highest
  heavy, heavier, heaviest
  light, lighter, lightest

Exclude finding the difference in length/mass.

Time
Include telling and writing time to the hour/half hour.
Exclude 24-hour clock.

Money
Include:
- identifying coins and notes of different denomination,
- matching a coin/note of one denomination to an equivalent set of coins/notes of another denomination,
- telling the amount of money
  - in cents up to $1,
  - in dollars up to $100.
- use of the symbols $ and ¢,
- solving word problems involving addition and subtraction of money in dollars only (or in cents only).

Exclude combinations of dollars and cents.

3. Geometry

Basic shapes:
- **rectangle**
- **square**
- **circle**
- **triangle**

Include:
- identifying and naming the 4 basic shapes from 2-D and 3-D objects,
- describing and classifying shapes.

Patterns
Include:
- making/completing patterns with 2-D cut-outs according to one or two of the following attributes
  - shape
  - size
  - colour
- making/completing patterns with 3-D models:
  - cube
  - cuboid (rectangular block)
  - cone
  - cylinder

4. Data Analysis

Picture graphs
Include:
- collecting and organising data,
- making picture graphs,
- use of a symbol/picture to represent one object,
- reading and interpreting picture graphs in both horizontal and vertical forms.

Exclude picture graphs with scales.

All BA/BSc in education candidates who are planning to teach upper primary grades also can pursue optional independent-study topics to strengthen their mathematical content knowledge, and expand and improve their range of teaching skills. Through these courses, teacher candidates are nurtured and equipped with the necessary skills and knowledge to teach mathematics effectively.

Experiential Education

Experiential education opportunities in local schools are an important part of teacher preparation. In Singapore, teacher candidates have multiple opportunities to apply and hone their knowledge and skills while gaining practical experience under the tutelage of their assigned mentors (who are teachers) and their NIE supervisor.

Teacher candidates are assigned to schools in each of their four years of undergraduate studies. In the fourth year, performance during the 10-week teaching practicum is evaluated.

For example, in the bachelor's degree programs, teacher candidates are assigned to schools in each of their four years of undergraduate studies.* At the end of their first year at the NIE, they have two weeks of school experience. At the end of the second year, they have a five-week school experience akin to a teaching assistantship in which they observe and learn from their "cooperating" teachers (teachers of the classes to which they have been assigned), who coach them in specific subjects, as well as help them reflect on teachers' responsibilities and roles. At the end of the third year, there is a five-week teaching practicum in which teacher candidates begin to become independent and responsible for teaching—they plan and teach their own lessons. They learn from observing their cooperating teachers and working with them on lesson preparation and delivery, as well as classroom management. Mentors, cooperating teachers, and staff from the NIE observe teacher candidates during select lessons and provide feedback, guidance, and support. In the fourth and final year, teacher candidates teach their designated grade level or subject during a 10-week period in which they are assigned to the same school where they were apprentices. They become actively involved in school life as they plan, teach, and learn through guiding and assessing their students, while still under the tutelage of their NIE supervisor and mentors. Some teacher candidates also become involved in afterschool activities such as enrichment, remedial, and supplementary classes.

In the fourth year, performance during the teaching practicum is evaluated. In order to successfully graduate from the NIE and qualify as trained teachers, teacher candidates must attain at least a passing grade. Teacher candidates who do not perform as expected or who are at risk of failing their practicum receive additional counseling and support from the school and the NIE. If they still fail, they may be offered a second chance to redo their teaching practicum at another school, which then delays their graduation. Teacher candidates who are deemed unsuitable or lacking the integrity necessary to be teachers, even after help and counseling, are asked to leave the teaching service (and, as noted above, must repay the MOE their tuition fees and stipend, with interest). Most student teachers successfully complete their teaching practicum and proceed to become full-fledged teachers in schools.

IV. Flexibility and Focus Throughout the Teaching Career

In Singapore, successfully completing a teacher-preparation program in no way signifies that a person has finished learning how to teach. Teachers continue upgrading their knowledge and skills throughout their careers. They are entitled to take 100 hours of professional development annually, paid for by the MOE. In fact, all educators, including teachers, department heads, vice principals, and principals, are strongly encouraged to develop their professional capabilities and competencies. The NIE and MOE regularly organize workshops, courses, and conferences. NIE staff members also provide customized school-based professional development, as well as lesson-planning input and individualized feedback based on lesson observations. Although the bulk of the 100 hours is dedicated to improving teachers' practice, teachers also can enroll in some courses to promote personal well-being. For instance, some may take a health-related course, subject to approval.

Professional Development Continuum Model

The MOE supports teachers who wish to pursue additional undergraduate (e.g., by upgrading from a Diploma in Education to a bachelor's degree) and postgraduate studies. As part of the Professional Development Continuum Model (PDCM)—a collaboration between the MOE and NIE—some NIE courses that are taken as professional development also provide credits that contribute to the pursuit of postgraduate degrees. Through the PDCM, teachers can attain advanced certification or pursue one of the 18 PDCM master's degree programs, including one Master of Education (MEd) degree focusing on mathematics education for primary and secondary teachers. PDCM postgraduate courses are fully paid for or largely subsidized† by the MOE.

The MEd in mathematics education consists of 10 courses taken over three years. The courses are designed to help teachers develop deeper knowledge of mathematics curriculum, content, and pedagogy, and greater expertise in the mathematical topics

(Continued on page 36)

*In the U.S., student teachers do not typically begin practica their first year.

†For MOE sponsorship, applicants must be Singapore citizens or permanent residents, have good evaluations at work during the year preceding the application, have at least an overall C grade for their university degree, have at least two years of teaching experience, and be employed by the MOE on a permanent basis.

Career Development

How Singapore Merges Teacher Professional Development and Evaluation

BY SUSAN SCLAFANI WITH EDMUND LIM W.K.

From their first year on the job, all teachers in Singapore are planning their careers and using self-assessment, coaching, and evaluation to achieve their next steps as professionals. To manage the process, in 2003, Singapore began implementing a comprehensive system, the Enhanced Performance Management System (EPMS). While the EPMS culminates in a final annual evaluation (which contributes to performance bonuses and promotions), it is actually a yearlong process that consists of setting goals, seeking out professional development courses and other learning opportunities, collaborating with colleagues, and assessing one's progress. Everyone takes the entire process very seriously. Teachers and reporting officers (a department head or vice principal) work together to enhance the teachers' performance and the performance of their colleagues through observations and coaching. But more important, teachers believe that the EPMS will help them become better teachers.

Through the EPMS process, teachers are encouraged to expand their teaching repertoire, improve their knowledge and skills in their selected career track,* and take those developmental actions that lead to greater competence—and higher levels on the career ladder. Teachers start the year with a self-assessment and develop their goals for (1) teaching, (2) instructional innovations and improvements at the school, (3) professional training, and (4) personal development. They discuss their goals and performance benchmarks with their reporting officer to ensure they are aligned with the department, school, and national goals and benchmarks. These meetings are opportunities to discuss where the teacher ended the previous year and what needs to be done next to reach his or her career goals. Reporting officers encourage teachers to improve and to reach their full potential. Together they decide on additional training or identify which teachers or department heads can best help with coaching. It is a collegial process focused on ensuring that teachers have the competencies to improve their capabilities as teachers as well as their students' learning and achievement. During the year, there are informal meetings, a more formal midyear evaluation, and then the final evaluation.

The EPMS is not an evaluation as we in U.S. education usually do it. The resulting document is a narrative that summarizes, at midyear and at the end of the year, the activities engaged in, progress made toward the goals set, and data on the agreed-upon performance benchmarks. It resembles our portfolio assessments, although it adds summaries of relevant discussions between the teacher and the reporting officer as well as evaluative narratives from both. These evaluations are based on the experience and current position of the teacher, since the level of competence expected of a new teacher is much lower than that expected of senior and master teachers.

The final annual evaluation includes not just an assessment of current performance, but also an assessment that is the reporting officer's view of the teacher's "Current Estimated Potential."

The decision on potential is made in consultation with senior teachers who have worked with the teacher, department and grade chairs, the vice principal, and the principal. While it is a subjective decision, it is based on their observations, discussions with the teacher, evidence in the portfolio, and knowledge of the teacher's contributions to the school and community. The estimate of potential is used to help the teacher grow and develop that potential.

Ultimately, teachers' annual evaluations determine their performance grade. The performance grade for the year affects the size of their performance bonus (which can range from one month's salary for performance that exceeds expectations in some areas, to more than two and a half months' salary for outstanding performance), as well as their progression in salary and position. The expectation is that all teachers are striving to be the best they can be. Because teachers understand and respect the evaluation system, they honor and endeavor to learn from the teachers who move up. At the same time, those who achieve the higher grades and eventually become subject, department, and grade chairs or senior teachers are expected to help their colleagues improve. ❑

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*See the main article for brief descriptions of the career tracks.

(Continued from page 34)

they are responsible for helping students master. About half the courses address issues related to mathematics education, including qualitative and quantitative research methods so teachers can engage in mathematics education research. The remaining courses are devoted to deepening teachers' knowledge of mathematics. Some of the courses include:

- How the Internet and multimedia can be used effectively as aids in teaching and learning mathematics.
- Current mathematics education issues from both overseas and local perspectives. Teachers examine and evaluate research studies and methodologies on effective mathematics curriculum, learning and teaching, and explore in depth multiple assessment practices, diagnostic assessment, and integrating assessment with instruction.
- Recent developments in curriculum models, design, and evaluation in relation to mathematics education, and their implications for the curriculum.

With regard to mathematics content, MEd mathematics education candidates learn in greater depth and breadth about selected topics such as algebra, geometry, and statistics, and about teaching these topics. There are also courses on discrete mathematics, number theory, and teaching arithmetic. In addition, teachers pursue an independent critical inquiry module in which they identify a problem, examine the relevant literature, and undertake data collection and analysis to address the problem. MEd candidates also gain an understanding of research and interpretation of research data.

Teachers sponsored through the PDCM pay a one-time fee of $1,500 upon registration, and the MOE pays for the minimum number of courses necessary to satisfy the degree requirements. However, if sponsored teachers fail or withdraw from the courses, they assume responsibility for the full cost. After completion of the master's program, graduates must remain employed with the MOE as teachers for one year.

V. Focus and Flexibility Are Important, but Effective Teaching Requires Ongoing Leadership and Support

The MOE works with schools and partners such as the NIE to boost the quality of education for teachers and students. It oversees education policies, and provides leadership and resources. It also provides autonomy to support the implementation of policies and programs in the schools and to empower leaders and teachers to make decisions that will help them teach more effectively. It supervises the management and development of the government and government-aided primary schools, secondary schools, junior colleges, and the Millennia Institute.* In addition, the MOE is involved in the administration of the nine polytechnics and the Institute of Technical Education, as well as the three universities and the NIE.

Over the past 10 years, the MOE has engaged in major initiatives to improve teachers' career paths, and to promote creative thinking, collaborative learning, and the use of information technology in schools. It has also provided schools with more autonomy and resources.

In order to attract and retain caring and capable teachers, the ministry periodically revises their salaries† and advancement prospects. For example, in April 2001, a comprehensive pay and career system was introduced to ensure that the teaching profession remains competitive with other careers. It includes new career and recognition structures, and refinements to the performance-management systems. There are now three career tracks: (1) the teaching track, which keeps teachers in the classroom‡ but also recognizes growth and accomplishments by identifying senior and master teachers and giving them responsibility for assisting their peers; (2) the senior specialist track, which encourages teachers to become subject or curriculum specialists and conduct education research; and (3) the leadership track, which offers opportunities to take leadership positions in schools and in the MOE. Within each of these tracks are positions at various levels such that all educators have clear goals and opportunities for advancing.[13] The means to accomplish those advancement goals are also clear: Singapore has an elaborate professional development and evaluation system (see "Career Development" on page 35).

Since 2000, most first-year teachers have been assigned 80 percent of the normal workload to provide additional time to learn from colleagues.

There are other efforts that help boost teachers' morale and performance. For example, since 2000, most first-year teachers have been assigned 80 percent of the normal workload to ease their adjustment to the teaching environment and provide additional time to learn from colleagues. Also, in an effort to continue the purposeful exchange and cross-fertilization of ideas between schools and the NIE, an educational exchange system was established. Selected school teachers have an opportunity to work at the NIE, where they teach, conduct courses, and share their school-based experiences, while some NIE staff members conduct research and immerse themselves in the school environment.

*Private schools also have to be registered so that the MOE can keep track of them.

†The starting salary of beginning teachers in Singapore is comparable to the starting salaries of accounting and engineering graduates.

‡In the U.S., competent teachers frequently are promoted out of the classroom.

Another recent change is that in 2004, the MOE enlarged the pool of teachers by implementing an Adjunct Teacher Program so that schools could rehire experienced and capable teachers who had retired or left the teaching service. In 2005, the MOE began employing more teachers, reducing the sizes of primary 1 (i.e., first grade) classes from 40 to 30 students. By 2010, the MOE plans to have 10 additional teachers in each primary and secondary school. The deployment of these extra teachers is left to the schools. For example, one school assigned a teacher to help small groups of students evaluated as being weak in mathematics. These groups of students leave the regular mathematics class in order to receive focused attention and support by the designated mathematics remediation teacher, who has deep knowledge of mathematics. When these children's understanding of mathematics improves, they rejoin their classmates for regular mathematics.

* * *

Some people may argue that lessons from Singapore cannot be applied in the United States, given the vast differences in size, policies, and culture between the two countries. For example, Singapore has one syllabus, while the United States has thousands of state and district mathematics standards. Singapore has one teacher-preparation institution; the United States has more than 1,400,[14] and their course requirements can range from no mathematics-content requirement (for those planning to teach grades 1–4) to requirements of several mathematics courses, with no consistency in content across institutions. In short, Singapore focuses on specific high standards (for teachers and students) and provides flexibility in attaining them. In the United States, curricular incoherence (in both K–12 education and in teacher preparation) means that only some teachers and students are held to high standards. As a result, the flexibility the United States offers leaves some students without a decent education and some teachers without decent preparation.

When it comes to mathematics content, differences between countries should play no role in determining what mathematics is learned. Mathematical coherence and rigor transcend national boundaries, as revealed by the similarity in the grades 1–8 mathematics taught in the six top-performing countries.[15] Interestingly, some of the effective educational strategies used in Singapore that are currently being adopted by other countries actually originated in these countries, including the United States. For example, Singapore's mathematics curriculum strategy of moving students carefully from the concrete to the pictorial to the abstract (thus offering a smooth, progressive transition from arithmetic to algebra[16] that is accessible to most students, rather than to a minority of students, as in the United States), was drawn from the work of the American psychologist Jerome Bruner.[17]

In the United States, there has been ongoing debate on what mathematics should be taught, but some positive news has emerged in the last few years. In 2006, the National Council of Teachers of Mathematics called for a more coherent and concise mathematics curriculum and suggested three big ideas for each grade level, from prekindergarten to grade 8.[18] Then, in 2008, the National Mathematics Advisory Panel reinforced the call for a coherent mathematics curriculum.[19]

In conjunction with a common, coherent curriculum, greater teacher knowledge of mathematics is also needed.[20] As recognized by a U.S. elementary school teacher, "one is only as effective as one's own level of understanding."[21] But most of our teacher-preparation programs are falling short. Last year, when the National Council on Teacher Quality studied dozens of mathematics education programs, it found overall low quality and enormous variability in course requirements.[22] Might it make sense for teacher-preparation institutions, at least in each state, to come together to review Singapore's required mathematics coursework for pre-service teachers, as guidelines for conversations about developing common, coherent mathematics courses?

Before one dismisses the content of this paper as unrealistic for consideration in the United States, let's examine what has been happening in Massachusetts. Since 2000, the state has made a concerted effort to align its standards, curriculum frameworks, and assessments. It has also begun to assess more seriously the content knowledge of those who aspire to be teachers, with a specific requirement that individuals must pass the mathematics portion of the state's certification test in order to be certified.[§] Since 2000, both the National Assessment of Educational Progress (NAEP) and the TIMSS mathematics results have documented Massachusetts's continuous improvement. Its students recorded the highest scores in the nation on the most recent NAEP. In addition, Massachusetts's students performed near the top internationally on TIMSS 2007.

Singapore continues to improve its educational system by learning from the strengths of other countries, including the United States. Singapore sends many leaders and talented students to earn degrees in the United States and also benefits from partnerships with American universities. For instance, the Singapore University of Technology and Design (opening in 2011) recently appointed Thomas Magnanti, former dean of the School of Engineering at the Massachusetts Institute of Technology, as its founding president.

As we in the United States move toward more coherence in our overall mathematics education system, we need better alignment of what students learn and what teachers know. In addition to content and pedagogy, we need to identify ways to attract and keep competent teachers in the classroom, and to develop a systematic and systemic infrastructure that is sustainable. In this process, there is much we may learn from Singapore's common, coherent curriculum and its dedication to teacher preparation, development, and retention. ☐

Endnotes

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[§]In some states, it is possible to miss all the mathematics items and still pass the overall certification exam.

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