A study of school mathematics curriculum enacted by teachers in Singapore secondary schools

The "Enactment Project" is a Programmatic Research Project funded by the Ministry of Education, Singapore, and administered through the Office of Educational Research, National Institute of Education, Nanyang Technological University. The project began in 2016 and its aim is to study the enactment of the Singapore mathematics curriculum across the whole spectrum of secondary schools within the jurisdiction. Under this overarching goal, there are two supporting studies: Study 1 examines the classroom enactment by teachers in relation to the curriculum framework as organised in the Pentagon (Skills, Concepts, Attitudes, Processes, Metacognition, with Problem Solving at its centre); Study 2 focuses on the enactment as seen through the instructional materials designed by the teachers.

Chair/Discussant: Berinderjeet Kaur

Paper 1: Toh Tin Lam, Berinderjeet Kaur, Tay Eng Guan, Lee Ngan Hoe, & Leong Yew Hoong *A study of school mathematics curriculum enacted by teachers in Singapore secondary schools.*

This paper provides an overview of the study, which covers the background, the organisation into two supporting studies, the methodology, and the phases of the project.

Paper 2: Berinderjeet Kaur, Lee Ngan Hoe, Ng Kit Ee Dawn, Yeo Boon Wooi Joseph, Yeo Kai Kow Joseph, & Liyana Safii *Instructional Strategies Adopted by Experienced Secondary Teachers when Enacting the Singapore School Mathematics Curriculum.*

This paper presents preliminary findings of Study 1. In particular, it examines the instructional strategies adopted by teachers in the first phase of the project – where thirty competent teachers were selected for close study, which included video-recording of a suite of lessons and post-lesson interviews.

Paper 3: Leong Yew Hoong, Cheng Lu Pien, & Toh Wei Yeng Karen *Chronologically-grounded survey.*

This paper describes a methodological contribution by Study 2. From Phase 1 of the project, we obtained some characteristics of design utilised by competent teachers. To study the extent in which these characteristics capture the design work of teachers across Singapore secondary schools, we developed an instrument: Chronologically-grounded survey.

Paper 4: Tong Cherng Luen, Tay Eng Guan, Berinderjeet Kaur, Quek Khiok Seng, & Toh Tin Lam *Singapore Secondary Mathematics Pedagogy: The DSR DNA.*

This paper reports findings from a statistical analysis of a survey on 689 teachers in the second phase of the project. In particular, it analyses data from 32 items in one component of the survey regarding teacher moves in the classroom.

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Instructional Strategies Adopted by Experienced Secondary Teachers when Enacting the Singapore School Mathematics Curriculum

Kaur, Berinderjeet
Nanyang Technological University
<berinderjeet.kaur@nie.edu.sg>

Lee, Ngan Hoe
Nanyang Technological University
<nganhoe.lee@nie.edu.sg>

Ng, Kit Ee Dawn
Nanyang Technological University
<dawn.ng@nie.edu.sg>

Yeo, Joseph B. W.
Nanyang Technological University
<josephbw.yeo@nie.edu.sg>

Yeo, Kai Kow Joseph
Nanyang Technological University
<kaikow.yeo@nie.edu.sg>

Safii, Liyana
Nanyang Technological University
<liyana.safii@nie.edu.sg>

Classroom instructional quality is seen as crucial to student learning. Of particular interest is the interpretation and enactment of the intended mathematics curriculum in Singapore schools by experienced mathematics teachers towards quality learning outcomes. This paper discusses the findings from the study which investigate the instructional strategies that are adopted by experienced mathematics teachers based on the intended Singapore school mathematics curriculum. Findings from the study provide important implications for educational policy makers and practitioners on improving teaching and learning.

Mathematical problem solving has been a focus of mathematics learning in Singapore schools since 1990 and has served as a frame of reference for the enactment of mathematics curriculum (Ministry of Education, 2012, p.14). Instruction in mathematics classrooms in Singapore is guided by a problem solving framework that encompasses a strong foundation on what is to be taught and learned in schools. This includes effective classroom instruction that is supported by three phases of learning (Ministry of Education, 2012, p.22): setting up the stage for students to learn (Readiness), fostering student's active role in learning (Engagement), and consolidating acquired knowledge and stretching student's thinking capacity (Mastery). When planning for classroom instruction, a typical lesson could be mapped out from these learning phases into four distinct phases of lesson (Lee, 2009):

1. Introduction, in which teachers foster student readiness by checking for mastery of pre-requisite knowledge and using motivating contexts (Readiness)
2. Development, in which teachers teach for attainment of the objective of the lesson (Engagement)
3. Consolidation, in which teachers provide opportunities for students to practice on tasks related directly to the objective of the current lesson (Mastery)
4. Closure, in which teachers summarise the lesson and assign homework or follow-up activity to set the stage for the next lesson (Mastery)

The Singapore School Mathematics Curriculum Framework highlights that fostering student problem solving competencies is dependent on five inter-related aspects: conceptual understanding, skills proficiency, mathematical processes, metacognition and attitudes (Ministry of Education, 2012, p.14). These five inter-related aspects support teachers in building a learning environment which is bounded by elements such as student-centredness, and diversity and creativity in learning. This framework has been sustainable, with little modification made to it, since its development in 1990 due to its rigour and robustness in

highlighting the philosophy and principles that influence decisions on what students should be equipped with within our mathematics education (Lee, 2008).

The intent of a curriculum framework is to set parameters for providing high quality learning opportunities to students while allowing some variations on how curriculum is enacted, on the condition that the prescribed standards are adhered to (UNESCO International Bureau of Education, 2017). This suggests that how the phases of lesson unfold in the classroom is extensive and largely dependent on the translation of the intended curriculum prescribed at the national level into the implemented curriculum characterised by instructional strategies adopted by teachers. While past studies have provided us with insights on general characteristics of mathematical instructional strategies in Singapore classrooms (e.g., Hogan et al., 2013; Hyun & Lee, 2017), there is a dearth in the investigation of how instructional strategies adopted in Singapore secondary schools compare to our robust School Mathematics Curriculum Framework.

This study is part of a programmatic research study that examines the instructional strategies and materials that experienced teachers adopt when enacting the intended mathematics curriculum in Singapore secondary schools. This paper reports preliminary findings on the instructional strategies that experienced mathematics teachers adopt as they enact the five aspects of problem solving prescribed in the Singapore School Mathematics Curriculum Framework.

Methodology

The study reported here is part of a larger study which consists of two phases. This study, which is the first phase of the larger study, involved 30 secondary mathematics teachers from 23 different schools who volunteered to participate in the study after being nominated. The purpose of this phase was to document the instructional strategies employed by experienced teachers. The teachers in our sample were recommended by their schools or professional community based on two requisites: (a) having taught the same course of study for at least 5 years, and (b) being recognised as having developed effective instructional strategies for his/her mathematics lessons.

Secondary education in Singapore is based on four different courses of study and our participants were selected such that our sample was representative of teachers from all the courses of study (see Table 1) as follows:

The second phase of the larger study, which will be reported elsewhere, examined how widespread the instructional strategies adopted by experienced teachers is in mathematics classrooms in Singapore.

Table 1
Number of Participants Teaching in Each Course of Study

Course of Study	Number of Participants
Integrated Programme (IP)	4
Express	10
Normal Academic (NA)	8
Normal Technical (NT)	8
Total	30

This paper focuses on presenting the preliminary findings from Phase 1. Here, teacher instructional strategies were mainly documented through lesson observations, which was also video recorded. The design for the video recording sessions was adopted from Clarke's

(1998) complementary accounts methodology. Each teacher was recorded for a series of consecutive lessons that complete one mathematics topic. The lessons were recorded by three video cameras: (a) teacher camera that focused on how the teacher delivers the lesson, (b) student camera which captured the actions of two selected students seated adjacent to each other, and (c) whole class camera that recorded the overall behaviour of the class. For the purpose of this paper, only recordings captured by the teacher camera would be analysed.

In total, 211 lessons that were video recorded were coded for analysis by a research team comprising experienced and knowledgeable mathematics educators. The data was coded with reference to the five aspects of problem solving prescribed in the Singapore School Mathematics Curriculum Framework (Ministry of Education, 2012, p.14): concepts, skills, processes, metacognition and attitudes.

Findings & Discussion

Introducing/ constructing Mathematical concepts: Our findings revealed that the experienced teachers in our sample adopted a cognitivist approach where the focus is on the assimilation of new information with student's prior mathematical knowledge and the accommodation of new information into student's pre-existing mathematical knowledge (Wadsworth, 1996). This was observed when teachers (n = 22) used a whole-class explanation approach to introduce students to new concepts in the classroom, while posing questions along the way. Teachers (n = 18) also employed a constructivist teaching approach (Bruner, 1961) by guiding the class or assigning students with tasks which serve to help them actively discover the concepts for themselves. These forms of classroom instruction include elements of cognitive engagement that enable students to understand how mathematical processes work, and the underlying relationships or connections that are crucial to problem-solving proficiency.

Developing students' fluency in skills related to computing or manipulating mathematical tasks: It appears that teachers deliver their lessons through single or multiple cycle(s) of development-consolidation phases, which involved cycles of teaching and review of student work. Half of the participants (n = 15) conducted their lessons in multiple cycles of development and consolidation of concepts or skills. These multiple cycles were observed within one lesson and within a series of consecutive lessons in which a whole chapter was taught. On the other hand, single cycle of development and consolidation of concepts or skills was used by 14 teachers when delivering lessons. Teachers ($n = 24$) also explained or showed the solution of one or a few worked example(s) prior to giving students questions for practice. The teachers placed emphasis on engaging students with mathematical concepts and provided opportunities for students to achieve mastery in learning through follow up practices which reinforce their understanding of new knowledge. These cycles are reflective of the engagement and mastery learning phases specified in our curriculum framework (Ministry of Education, 2012).

Emphasizing mathematical processes and developing students' metacognitive strategies: Teachers (n = 18) made thinking visible to encourage articulation of reasoning and metacognitive awareness by presenting students with opportunities to explain and justify their solutions or their peers' solutions to a problem. Teachers (n = 13) also fostered metacognitive regulation by making students compare different ways of solving a mathematics problem.

Imbuing desired attitudes towards Mathematics learning: Teachers addressed the affective aspects of learning by (a) giving students tasks that they were competent at before progressing to more challenging tasks to foster their confidence in doing mathematics (n = 16), and (b) encouraging perseverance in their mathematics learning (n = 13).

The abovementioned instructional strategies were found to be demonstrated fairly consistently across all courses of study, except the imbuement of desired learning attitudes. Relatively lower proportion of IP teachers assigned time and resources towards building positive student learning attitudes as compared to teachers from the other three courses of study. This variation suggests that teachers deem it necessary to serve different student needs more efficiently; teachers saw a need to develop positive self-concepts that could bolster the learning process for students who are not in the IP, whereas students in the IP could have been seen as self-sufficient in this aspect.

Conclusion

Setting it apart from past studies, this study scrutinised how experienced teachers in Singapore direct their lessons to maintain high quality of mathematics learning that is guided by a robust framework. Our findings revealed that the instructional strategies established by our experienced teachers are aligned to the intended objectives prescribed by our problem solving framework. These insights have implications on policy makers and practitioners on using a curriculum enactment framework to guide pre-service teachers to evaluate and reflect on their teaching practices as beginning teachers, and to improve instructional strategies for in-service teachers.

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