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Enhancing the Pedagogy of Mathematics Teachers (EPMT): An Innovative Professional Development Project for Engaged Learning

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Abstract: Enhancing the pedagogy of mathematics teachers (EPMT), a school based project of the Centre for Research in Pedagogy and Practice at the National Institute of Education of Singapore is an example of an innovative project that exemplifies a critical development in the professional development of teachers in many parts of the world. The aims of the EPMT project were three fold. The first was to engage mathematics teachers in professional development (PD) to improve their classroom pedagogy and ultimately improve student learning in terms of understanding, reasoning and communication skills in mathematics lessons. The second was to create teacher practitioner learning communities at the school level who will work together to advance the knowledge they gain from the professional development modules and also put it into practice; and the third was to enthuse and support teachers to put together their work in print form and showcase it to other fellow teachers. This paper focuses on only two sub research questions of the project, i.e. "Did the teacher participants of the project find the model of professional development as enacted by the EPMT project an innovation? How was it different or similar from traditional in-service courses they normally attended?" and "How did the strategies explored during the PD for "reasoning and communication" impact student learning?" The qualitative responses from the project participants affirm that the EPMT project was an innovative one, which not only was distinctively different from traditional in-service courses they normally attended but it also impacted student learning in their classrooms in meaningful ways.

Key words: Professional development, Mathematics teachers, Expert teacher knowledge, Singapore, School-based

Introduction

Enhancing the pedagogy of mathematics teachers (EPMT), a school based project of the Centre for Research in Pedagogy and Practice at the National Institute of Education of Singapore is an example of an innovative project that exemplifies a critical development in the professional development of teachers in many parts of the world. This development reflects a gradual shift in the centre of gravity away from the University-based, "supply-side", "off-line" forms of knowledge production

conducted by university researchers for teachers towards an emergent school-based, demand-side, on-line, in situ forms of knowledge production conducted by teachers for teachers. Supporters of this transition do not deny the value of university based research but they do insist that in a knowledge economy, improving the quality of teaching and learning is going to depend increasingly on carefully crafted partnerships between university scholars and classroom teachers. Critically, they also insist that one key outcome of such partnerships ought to be the codification, verification, dissemination and institutionalization of expert teacher knowledge.

The aims of the EPMT project were three fold. The first was to engage mathematics teachers in professional development to improve their classroom pedagogy and ultimately improve student learning in terms of understanding, reasoning and communication skills in mathematics lessons. The second was to create teacher practitioner learning communities at the school level who will work together to advance the knowledge they gain from the professional development modules and also put it into practice; and the third was to enthuse and support teachers to put together their work in print form and showcase it to other fellow teachers.

Groups of mathematics teachers from ten schools, five secondary and five primary, participated in the project for two complete academic years, i.e. from January 2007 till December 2008. The two-year long programme of the project comprised of school-based professional development activities conducted by the university researchers (one of which is the author of this paper) for the teacher participants, sharing by teacher participants amongst themselves showcasing their work with students during mathematics lessons which resulted from their participation in the professional development activities and critique of resources produced by teacher participants for the community of mathematics teachers in Singapore schools.

Professional Development of Mathematics Teachers

In 1997, Mr Goh Chok Tong the Prime Minister of Singapore in his speech (Goh, 1997) at the opening of the Seventh International Conference on Thinking held in Singapore noted that Singapore has a strong education system, one that is widely recognized for having produced high levels of achievements among pupils of all abilities. However, he also cautioned that what may have worked well in the past will not work well for the future as the old formulae for success are unlikely to prepare the young Singaporeans for the new circumstances and new problems they will face in the new millennium. He emphasized that we must ensure our young can think for themselves, so that the next and future generations can find their own solutions to whatever new problems they may encounter. He announced at the opening of the conference that Singapore's vision for meeting this challenge is

encapsulated in four words: THINKING SCHOOLS, LEARNING NATION (TSLN).

With the unveiling of the TSLN vision, it was realized that teachers are the key to the success of the mission and hence their on-going professional development (PD) is critical. Since 1998 all teachers in Singapore are entitled to 100 hours of training and core-upgrading courses each year to keep abreast with the current knowledge and skills. The PD is funded by the Ministry of Education. Yet another subsequent development that has accorded teachers the responsibility of their own professional development is the Enhanced Performance Management System (EPMS) (Ministry of Education, undated) put in place by the Ministry of Education (MOE) in 2005. The EPMS is an appraisal system that contains rubrics pertaining to fields of excellence in the education system be it teaching, leadership or senior specialist. Over the past couple of years, mathematics teachers have been focused on excellence in their mathematics classrooms.

What Counts as Professional Development of Teachers?

Upon the completion of pre-service education, teachers continue their learning journey through participation in many types of PD activities. For a long while the most common traditional type of PD in Singapore has been in-service courses. These courses are conducted for about 3 hours each day either for about 10 consecutive days or for days spread over a number of weeks. They are conducted by experts in the field and are "off-line" forms of knowledge production. After the completion of the course there is no follow up with the teachers about the use of the knowledge acquired and any impact that knowledge may have had on student achievement.

Over time the nature and scope of PD has expanded and at present it includes any activity and interaction that may increase the knowledge and skills and improve teaching practice. These experiences can range from formal, structured topic-specific seminars, workshops to school-based activities involving curriculum design, discussions on instruction techniques, day to day collaborative activities that enhance teachers' knowledge and skills, co-teaching, peer observation, mentoring, etc.

The EPMT Project

Rational

This intervention project, in the area of mathematics classroom pedagogy, addressed two main issues: the nature of mathematical learning tasks that enhance students' reasoning and communication in mathematics classrooms, so as to help them develop habits of mind necessary for higher order thinking, and teaching for

understanding rather than assessment. The impetus for this project arose from three main issues. The issues were:

i. The findings of a project "Student perspective on effective mathematics pedagogy: stimulated recall approach" (Kaur, in press) that showed that Singapore teachers were generally bound in their choice of "learning tasks" (tasks used by the teacher during instruction to develop a concept or demonstrate a skill or process) available in the textbook used by the school and that these tasks are not suitable to engage students in reasoning (logical, deductive or inductive) and communication (explaining the process / thinking either during oral presentations or in writing). In addition, the lessons observed as part of the project did not make explicit the need to understand but rather placed emphasis on procedural knowledge, i.e. to remember algorithms and use them correctly to pass tests and examinations (Kaur, Seah & Low, 2005).

ii. The revised framework for mathematics implemented in 2007 by the Ministry of Education (Ministry of Education, 2006a, 2006b) expanded the scope of Processes to include
   - Mathematical reasoning, communication and connections
   - Thinking Skills
   - Heuristics

   Teachers were familiar with thinking skills and heuristics as both have been apart of the framework for the last decade. As mathematical reasoning, communication and connections were new attributes in the framework implemented in 2007, there was a need to work with teachers in this area.

iii. The criticism raised in the American Institutes for Research (AIR) Study comparing the quality of US elementary school mathematics instruction with that of Singapore's, a recognized world leader, about primary school mathematics instruction in Singapore schools lacking emphasis on 21st century thinking skills, such as reasoning and communication (Ginsburg, Leinwand, Anstrom & Pollock, 2005). The AIR study was one that compared textbooks used in US elementary schools and Singapore primary schools. It is evident from this study that the nature of mathematical tasks present in Singapore school textbooks lack emphasis on reasoning and communication which facilitate higher order thinking skills but rather highlight practice exercises that emphasize procedural knowledge and readiness for examinations.

Theoretical Framework and Design of Project

The design of this intervention professional development (PD) project was guided by research findings of effective PD programmes (Ball & Cohen, 1999; Wilson & Berne, 1999; Carpenter, et al., 1999; Stiff, 2002; Desimone, 2009). The five significant features of the EPMT project were:

Content focus. The project was specific to the pedagogy of mathematics

Coherence . The project was coherent with the needs of the teachers:

i. The revised math curriculum of 2007 placed emphasis on reasoning and communication in math lessons. Textbook questions were inadequate for the purpose, therefore need to learn how to craft mathematical tasks that facilitate reasoning and communication during math lessons.

ii. Teachers rely very heavily on textbooks for their daily work, therefore the need to learn how to use a textbook question as a starting point and craft a task that would engage students in reasoning and communication.

iii. With TLLM in place, more emphasis on teaching for understanding hence the need to learn about lessons that facilitate "understanding" and how to plan such lessons.

Active learning. Teachers were engaged in hands on work, they crafted mathematical tasks and planned lessons, worked in pairs to video tape their lessons, critique their lessons, revise their plans, thereby engaging in iterative cycles of planning and implementing.

Duration. The duration of the project was 2 years [teachers attended 60 hours of instruction spread over 6 months, these sessions were conducted by "experts" in the field one of which is the author of this paper followed by 6 months of school based work guided and monitored by the researchers of the project, followed by another year of self-directed school based work by teachers in the project].

Collective participation. At least 4 teachers, with 2 teachers teaching the same grade year and math programme, participated from each school, worked together in implementing their learning in classrooms and formed a "learning community" at the school level. These teachers worked collectively, building their knowledge, putting it into practice, critiquing their peer's work, participating in sessions organized by the "experts" (for the entire duration of the project) during which teachers shared their experiences and difficulties encountered during the implementation of their newly gained knowledge, showed to others video's of their

students interactions in class and collectively planned for conference presentations and worked on resources they put together for fellow teachers in Singapore with the hope of lighting many more fires across the educational system.

Research Questions

The main research question that guided the EPMT project was "How effective was a blended approach to Professional Development for mathematics teachers in Singapore schools?" In the context of the question "blended" means an integration of expert knowledge into the practice of teachers. There were several sub-questions.

The two sub-questions that would be addressed in this paper are:

1. Did the teacher participants of the project find the model of professional development as modelled by the EPMT project an innovation? How was it different from traditional in-service courses they normally attended?
2. How did the strategies explored during the PD for "reasoning and communication" impact student learning?

Research Methods

Subjects

Table 1 shows the numbers of schools and teachers who participated in the project from January 2007 till December 2008. A requirement for participation in the project was that a group of at least 4 teachers per school had to participate.

Table 1
Number of Schools and Teachers in the Project

	Primary	Secondary
Number of schools in the project	5	5
Number of teachers in the project for the 1st year (Jan 2007 – Dec 2007)	20	28
Number of teachers in the project for the entire duration (Jan 2007 – Dec 2008)	18	22

During the second year of the project 2 teachers from the primary schools and 2 teachers from the secondary schools were on maternity and child care leave. Four teachers from the secondary schools moved schools at the beginning of the second year and hence were unable to continue with the project.

Data collection methods and instruments

Data was collected for the project using survey instruments and open-ended prompts that required participants to give qualitative accounts of their experiences, feelings and preferences. Observational data was collected using videos. The survey instruments and open-ended prompts were specifically crafted for the specific purposes by the researchers. The video data was collected by the participants with minimal interference by the researchers.

Development of the project - the learning journey of the teacher

The project started in Jan. 2007, with the participants completing a pre-intervention teacher questionnaire and videotaping a good lesson of theirs for later use. The teachers attended two PD course conducted by 'experts' in the period Jan. 2007 – May 2007. The first PD dealt with the design of tasks that engaged students in reasoning and communication and the next dealt with teaching for understanding. Both PD courses adopted a workshop style and teachers met for 3 hours each week to work with the experts and fellow teachers in the project. Details of the PD courses are reported elsewhere (Kaur & Yeap, in press). From July 2007 till Nov. 2007, teachers worked at their respective schools to implement their learning into their lessons and videotaped their lessons for sharing and discussion. The project teachers continued to meet as a group on a monthly basis. During the meetings they shared their experiences with each other, showed video clips of their lessons and problem solved together. In Nov. 2007, they submitted their best lesson on a videotape to the researchers. During the second year of the project, i.e. 2008, the researchers kept in touch with participants through e-mail contact. Participants were encouraged to continue working in their schools to put into practice their learning and share their knowledge with others who may be interested in it. Two whole group meetings were organized for them to catch up with each other and also work on project matters. In July 2008 they met to review the drafts of the resource books in which their work was showcased and in September 2008 they came together to complete the final survey questionnaire.

Data and Analysis

Specific to the theme of this paper, the data and analysis of only two items below are presented in this paper. These items were part of the final survey conducted for the participants towards the second year of the project.

i. Tell us how different or similar has it been participating in the project compared to attending a traditional in-service course? Which would you prefer to participate or attend in the future?

ii. In what ways did the strategies explored during the PD for "reasoning and communication" help to improve student learning in your classrooms?

Results

A total of 33 participants of the project, 16 from primary schools and 17 from secondary schools completed the final survey questionnaire of the project in September 2008. The overall response rate was 82.5%. The qualitative responses of the items were analysed using content analysis. The responses to each question were first scanned through for common themes, following which codes were generated and the data coded. Inevitably "a progressive process of sorting and defining and defining and sorting" (Glesne, 1999, p. 135) led to the establishment of the final list of codes for the themes.

Tell us how different or similar has it been participating in the project compared to attending a traditional in-service course? Which would you prefer to participate or attend in the future?

Table 2, shows examples of the responses to the above question and inferences made.

Table 2
Content Analysis of Data

Teacher code	Response	Inferences
P-6	Participating in the project as a participant has its merits. ***Being with colleagues, we were able to work and learn together***. It was also good to attend the 2 PD courses with colleagues as we got to encourage on one another and share our experiences. We were also able to see how ***the new skills could be applied to our pupils at large***. The two year-long project was a journey of reflection and improving on my teaching methodologies. Attending the PD courses during term time was apt as I was able to ***apply the strategies at school*** and ***to see how the pupils respond to the strategies***. I was glad to be ***able to 'stretch' them more and probe further into their understanding***. The ***process on reflection was beneficial for my personal growth*** as I reflected upon the good and 'bad' instances of the lessons. Attending an in-service course is another viable way of improving content/pedagogical	More useful Merits (i) Collaborative work – learning community (ii) Put into practice almost immediately the learning and evaluate outcomes – impact on student learning (iii) Engaged in reflection (iv) Able to contribute towards the development of other teachers

	knowledge. However, they tend to be during the holidays or a one-off incident (as in 24 hours). Usually, they will be a mini assignment to 'show' our understanding. Hence, the impact may not be that significant. I would prefer to be part of a project where there is a system of reflection, PD courses and the opportunity to work with colleagues (which is like a small community). I believe the impact will be greater as through the project, the **community of practice** (formed by the teachers in the project) can go on to **influence and excite the others**.	
S-12	Participating in the project has been more fruitful as the **outcomes are more specific**. We are able **to work** on assignments together **as a group** and then **try out the tasks in our classes**. Sometimes we are excited by ideas when attending a course but are unable to bring these ideas to xxx due to time or manpower constraints in school. Another difference is that Prof. Kaur is able to **guide us throughout the project** whereas a trainer in a course may not be able to provide any other support after the workshop.	More useful Merits (i) Outcomes are specific (ii) Collaborative work (iii) Implement learning (iv) Sustained support from expert

Table 3 shows that 85% of the teachers who participated in the project found it more useful, compared to traditional in-service courses.

Table 3
Usefulness of the project

Response	No of Responses (%)		
	Primary n=16	Secondary n=17	Total n=33
More useful	12 (75%)	16 (94%)	28 (85%)
No preference	1 (6%)	1 (6%)	2 (6%)
Not useful	-	-	-
No response	3 (19%)	-	3 (9%)

Table 4 shows the differences between the project and traditional in-service courses, as perceived by the teachers in the project.

Table 4
Differences between the project and traditional in-service courses

Dimension	Project	Traditional In-service Courses
Content Knowledge	Co- construction of knowledge by participants and expert.	Mainly dissemination of knowledge by an expert.
Duration	Substantive	Very short
Participation	Collaborative – community of learners A few teachers from a school amongst participants – intra school peer support Like minded teachers from several schools	Mostly individual participation and may not know fellow participants
Learning	Active More transfer of learning Reflection – a must Learning from each other during scheduled sharing sessions Critiquing work of peers	Mostly passive Less transfer of learning
Implementation	Participants are required to implement their learning almost immediately	Not much scope for implementation
Evaluation	Participants able to evaluate their learning; check for affirmation from students and fellow colleagues	Seldom there is an opportunity for participants to evaluate their learning.
End product	Resource package – contributions from all teachers in the project Continue work beyond project and contribute towards the development of other teachers	Assignment, usually done individually – seldom have access to the other participants assignments.
Coherence	Specific, relevant and support the needs of teachers	May not directly support the needs of teachers
Support from Expert	On-going	One time

In what ways did the strategies explored during the PD for "reasoning and communication" help to improve student learning in your classrooms?

Table 5, shows examples of the responses to the above question and inferences made.

Table 5
Content Analysis of Data

Teacher code	Response	Inferences
P-2	Pupils were more engaged and they found the Math lesson interesting.	Lesson – interesting Pupils – engaged
P-14	Students could verbalise using the correct mathematical language (at most times). Students became more critical of their answers.	Students – verbalise thoughts; critical of their answers
S-8	It took their focus away from memorizing formula, and to how formulas are derived. The process makes them verbalized their thinking and increase retention of knowledge.	Lesson – shift of focus from rote learning to conceptual understanding Students – verbalise their thinking
S-11	The students were more engaged.	Students – engaged

Table 6, shows the changes in the behaviours of students and likely cause.

Table 6
Change in the Behaviours and Likely Cause

Primary pupils		Secondary students	
Change	Due to	Change	Due to
More alert, Motivated, Engaged	Lessons were fun and interesting because of activities designed by teachers	Motivated Engaged	Lessons had activities that were varied, fun, and thought provoking

Explored their understanding of mathematical concepts Explored alternative approaches to solve a task Verbalised their thoughts, often using mathematical language, and clarified their understanding	The nature of tasks they were given to do	Questioned their understanding of concepts Shift of focus from rote learning to how the formula/generalisation came about Verbalised their thoughts , clarified their understanding and increased retention of knowledge Increased use of logical thinking, analytical thinking Confidence of weak students improved	The nature of tasks they were given to do
Critical of their answers More aware of likely mistakes Were more reflective	Emphasis on nurturing good habits of mind	Self assessed their learning Were more reflective	Emphasis on nurturing good habits of mind

Findings and Discussion

In this section, we discuss the findings of the two sub research questions explored in this paper. The first sub research question is "Did the teacher participants of the project find the model of professional development as modelled by the EPMT project an innovation? How was it different from traditional in-service courses they normally attended?" Table 3 shows that 85% of the participants in the project found it more useful than a traditional in-service course in the context of PD for teachers in Singapore schools. As shown in Table 4, they also found it distinctively different from the traditional in-service courses they usually attended. The differences highlighted by the teachers addressed

i. The coherence and duration of the project – address their needs and provide for adequate time to work through their newly acquired knowledge;

ii. the manner in which the content knowledge was dealt – teachers preferred to be co-constructors of knowledge versus passive receivers;

iii. the nature of participation – preference was for collaborative versus individual;

iv. the mode of learning – they wanted to be actively involved, i.e. discussing, doing, sharing, critiquing, reflecting;

v. the scope of implementation of their learning – they wanted to experiment with their learning in the classrooms almost immediately;

vi. the impact of their learning on student outcomes – they wanted affirmation from their students, fellow teachers;

vii. support from experts in the field – preferred sustained support versus one-off kind of encounter;

viii. contribution towards the learning of fellow teachers at large – teachers wanted to be empowered to contribute towards the development of teachers after their participation in the project.

In view of the differences that the project participants highlighted, it may be claimed that the teacher participants found the EPMT project an innovation. It was certainly different from the traditional in-service course they normally attended and one that addressed their needs much better. The EPMT adopted a blended approach to PD is Singapore schools thereby integrating expert knowledge into the practice of teachers.

The second sub research question is "How did the strategies explored during the PD for "reasoning and communication" impact student learning?" From Table 6, it is apparent that students found lessons engaging when their teachers infused their learning about how to enhance students reasoning and communication in mathematics classrooms. They found the lessons interesting, as the activities were more engaging, required them to "think about what they were doing", talk about it with fellow classmates and present their work to the class. In so doing, they verbalised their thoughts, clarified their thinking and used mathematical language. Pupils in primary schools had the opportunity to explore various approaches to solve a task, in particular word problems. Students in secondary schools shifted their focus from "memorising the formulae" to how the formulae came about, were engaging in logical thinking and analytical thinking more frequently. Teachers also

noted that the confidence of weak students improved when they worked in groups on tasks that demanded more "reasoning" than procedural work. Most importantly, there were signs that good habits of mind specific to the learning of mathematics were being nurtured, such as being reflective, aware of possible mistakes, being critical and regulation of learning through self assessment.

Conclusion

Based on the findings from the two research sub questions of the project discussed in this paper it may be concluded that the EPMT project was an innovative professional development project for engaged learning. It was significantly different from traditional in-service courses that teachers normally attended. The project was a novel attempt to integrate expert knowledge into the classroom practice of teachers. Hence it is befitting to say that it blended two aspects of professional development of mathematics teachers in Singapore, i.e. expert knowledge and classroom practice. In addition the project successfully fulfilled the three aims it set out to, viz-a-viz, engage mathematics teachers in professional development to improve their classroom pedagogy, create teacher practitioner learning communities at the school level and enthuse and support teachers to put together their work in print form and showcase it to other fellow teachers.

A significant milestone of the project has been the production of two publications, Kaur and Yeap (2009a, 2009b), by which teachers have successfully contributed towards the development of fellow teachers in Singapore.

Reference

Ball, D. L. & Cohen, D. K. (1999). Developing practice, developing practitioners: Towards a practice-based theory of professional education. In L. Darling-Hammond & G. Sykes (Eds.), *Teaching as the learning profession: Handbook of policy and practice* (pp. 3–32). San Francisco: Jossey-Bass.

Carpenter, T. P., Fennema, E., Franke, M. L., Levi, L., & Empson, S. B. (1999). *Children's mathematics: Cognitively Guided Instruction*. Portsmouth, NH: Heinemann.

Desimone, L. M. (2009). Improving impact studies on teachers' professional development: Toward better conceptualisations and measures. *Educational Researcher*, *38*(3), 181–199.

Ginsburg, A., Leinwand, S., Anstrom, T. & Pollock, E. (2005). *What the United States can learn from Singapore's world-class mathematics system and what*

Singapore can learn from the United States: An exploratory study. Washington, D.C.: American Institutes for Research.

Glesne, C. (1999). Becoming *qualitative researchers: An introduction* (2nd ed.). New York: Longman.

Goh, C. T. (1997). Shaping our future: "Thinking Schools" and a "Learning Nation". *Speeches* (Vol. 21(3), pp. 12–20). Singapore: Ministry of Information and the Arts.

Kaur, B. (in press). A study of mathematical tasks from three classrooms in Singapore schools. In Y. Shimizu, B. Kaur, R. Huang, & D. Clarke (Eds.), *Mathematical Tasks in Classrooms around the World* (pp. 00–00). Sense Publishers.

Kaur, B. & Yeap, B. H. (in press). *Enhancing the pedagogy of mathematics teachers to emphasize understanding, reasoning and communication in the mathematics classrooms.* Singapore: National Institute of Education, Centre for Research in Pedagogy and Practice.

Kaur, B. & Yeap, B. H. (2009a). *Pathways to reasoning and communication in the primary school mathematics classroom*. Singapore: National Institute of Education, Centre for Research in Pedagogy and Practice.

Kaur, B. & Yeap, B. H. (2009b). *Pathways to reasoning and communication in the secondary school mathematics classroom*. Singapore: National Institute of Education, Centre for Research in Pedagogy and Practice.

Kaur, B., Seah, L. H. & Low, H. K. (2005). *A window to a mathematics classroom in Singapore – Some preliminary findings.* In Redesigning pedagogy: Research, policy, practice 30 May – 1 June 2005. Singapore: Centre for Research in Pedagogy and Practice, National Institute of Education. Retrieved Dec 31, 2009, from http: //conference.nie.edu.sg/rprpp.

Ministry of Education. (undated). *Enhanced Performance Management System.* Singapore: Author

Ministry of Education (2006a). *Mathematics Syllabus – Secondary*. Singapore: Author

Ministry of Education (2006b). *Mathematics Syllabus – Primary*. Singapore: Author

Stiff, L. V. (2002, March). Study shows high-quality professional development helps teachers most. *NCTM News Bulletin*, *38*(7), 7.

Wilson, S. M. & Berne, J. (1999). Teacher learning and the acquisition of professional knowledge: An examination of research on contemporary professional development. *Review of Research in Education*, *24*, 173–209.

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