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Continuing professional development of mathematics teachers in Singapore

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ABSTRACT: *Continuing professional development (CPD) of mathematics teachers may take several forms. Some of these involve merely the dissemination of knowledge by experts while others involve teachers in creating knowledge for and through practice. Research has shown that effective CPD for mathematics teachers involve experimenting in their classrooms and reporting back to a group, working collaboratively with fellow teachers, having time away from school to think and discuss common issues they faced in their classrooms and in addition to the pedagogical aspects of their deliberation also doing some mathematics. This paper presents a form of CPD that exemplify a shift of the centre of gravity for CPD from the "supply-side," "offline" forms of knowledge transmission by professional development providers, such as University academics, to "demand-side," "online" in-situ forms of knowledge creation by teachers. It involves a hybrid one that integrates the "training model of PD" with sustained support for mathematics teachers to integrate knowledge gained from the PD into their classroom practice. Here CPD is nestled in the classrooms of the teachers, and addresses their needs. The three phases of the CPD, namely: Learn (Acquisition and co-construction of knowledge), Apply (integrate new knowledge into classroom practice) and Teach (develop fellow teachers nationally and/or internationally) appear to make the engagement of teachers in CPD holistic.*

KEYWORDS: **Continuing professional development, hybrid model, mathematics teachers, teacher agency, teachers' voice.**

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1. Introduction

In 1997, at the opening of the Seventh International Conference on Thinking in Singapore the then Prime Minister of Singapore, Mr Goh Chok Tong, emphasized to Singaporeans that:

"We must set up comprehensive mechanisms to continually retrain our workforce, and encourage every individual to engage in learning as a matter necessity. Even the most well educated worker will stagnate if he does not keep upgrading his skills and knowledge. Every organization must first recognize the importance of the matter. It must require that its employees go through regular learning as a routine part of working life" (Goh, 1997).

In response to the call by the Prime Minister the initiative "Thinking Schools, Learning Nation" was launched by the Ministry of Education. This placed the continuing professional development (CPD) of teachers under the spotlight. Much thought was put into how best teachers could engage in continuing professional development. A framework to meet the challenge of building a team of high-quality teachers was developed by academics at the National Institute of Education together with school leaders and teachers. Several premises underpinned the what and how of CPD of teachers, which were as follows:

- All teachers and managers be involved in ongoing development and account regularly for their learning and professional growth.
- All development activity meets the needs of the school and of the individual professional. It is guided by the school and department goals for relevance and practicability.
- Most of the development activities be team-based and take place 'on the job'. This is where the greatest learning can occur. It should be part and parcel of a teacher's daily work.
- Expert resources may be necessary for the development activities. However, schools need to steer their developmental trajectories (Scott, 2000, p. 11).

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mathematics teachers may take several forms. As noted by Kennedy (2005), these forms range from training to transformative practice and they involve increasing capacity for teacher professional autonomy. There are three main forms of PD that mathematics teachers in Singapore schools participate in. The first is individual, where teachers enroll in award-bearing courses at institutions of higher learning. The second is school-based professional development, where teachers in a school form teams and work on specific issues related to their pedagogy and student outcomes. The third is project-based where teachers from several schools develop themselves by working and learning collaboratively. Often such projects are driven by national level curriculum initiatives and issues of concern. Both school-based and project-based professional development may lend themselves in forming professional development communities. Our work at the National Institute of Education (NIE) in Singapore with mathematics teachers with regards to CPD has resulted in the development of a hybrid model of CPD. In the following section we detail the model and teachers work in two CPD projects.

2. The hybrid model of continuing professional development

The hybrid model of CPD (Kaur, 2011) integrates the "training model of PD" (Matos et al., 2009) with sustained support for teachers to integrate knowledge gained from the PD into their classroom practice. It is a form of CPD that exemplifies a shift of the centre of gravity for CPD from the "supply-side", "offline" forms of knowledge transmission by professional development providers, such as University academics, to "demand-side," "online" in-situ forms of knowledge creation by teachers. Two projects carried out in Singapore in the last decade, the EPMT-RC (Enhancing the Pedagogy of Mathematics Teachers [Reasoning and Communication]) (Kaur, 2009; 2011) and the EPMT-TfM (Enhancing the Pedagogy of Mathematics Teachers [Teaching for Metacognition]) (Kaur et al., 2017) have validated this model of CPD to be effective. This model has five critical features.

The five critical features

Content focus

The projects focused on what to teach and how to teach (Stiff, 2002; Desimone, 2009). Teacher inputs shaped the foci of the projects that engaged participants with mathematical content appropriate for the grade levels of their students.

Coherence

Ball and Cohen (1999) have argued that classroom activities can form the basis of constructive professional development, and many other researchers have also determined that effective PD is embedded in teacher work (Clarke, 1994; Abdal-Haqq, 1995; Hawley & Vali, 1999; Carpenter et al., 1999; Elmore, 2002). The projects were also coherent with the needs of the teachers. They supported the instructional activities of teachers at school, such as the adoption of new initiatives (Stiff, 2002; Desimone, 2009).

Duration

The duration of the projects was two years and each comprised three phases, that can best be categorized as Learn (acquisition and co-construction of knowledge), Apply (integrate new knowledge into classroom practice) and Teach (develop fellow teachers nationally and/or internationally) (Kaur et al., 2017). In the Learn phase teachers attended workshops for a semester during which they explored ideas and worked collaboratively creating materials for their use in their classrooms, followed by the Apply phase of a semester of school-based work guided and monitored by the PD providers who were university mathematics teacher educators and lead teachers. The last Teach phase was a year-long, i.e., 2 semesters, of self-directed school-based work during which teachers were encouraged to contribute towards the development of fellow teachers. The duration of the projects was significantly longer than most in-service courses that mathematics teachers normally attended.

Active learning

The projects also engaged teachers in active learning (Wilson & Berne, 1999; Desimone, 2009). They included training, practice and feedback, and follow-up activities (Abdal-Haqq,

1995), consistent with Stiff (2002), who suggested that teachers learn best when observing, planning for classroom implementation, reviewing student work, and then presenting, leading, and writing. As stated earlier, Ball (1996) also claimed that the most effective professional development model includes follow-up activities in the form of long-term support, coaching in teachers' classrooms, and on-going interactions with colleagues.

Collective participation

In the projects, there was collective participation at two levels – school and project. At the school level, at least four teachers participated, with pairs of teachers teaching the same grade year and mathematics programme. At the project level, all the teachers from the participating schools were involved. Teachers worked together during the knowledge-building workshops and also project meetings during which they critiqued their peers' work and shared their experiences and difficulties encountered during the implementation of their newly gained knowledge into their classroom practice. At the school level, teachers from the respective schools worked together integrating their newly gained knowledge into their classroom practice.

3. Teacher agency and communities of practice

It is noteworthy that recruitment for participation in the projects was through large group meetings at the cluster levels (note: schools in Singapore belong to clusters in their zones: north, south, east and west) where following dissemination of details about the projects, teachers were invited to form a group of 4 or more from a school and indicate their interest to the PD providers. A bottom-up approach was adopted. The only involvement of the leadership of the schools was consenting their participation so that on afternoons when project-related meetings were held, teachers were not scheduled for any school duty. This process of recruitment was adopted to avoid any pressure from school leaders for teachers to participate in the projects, as we know that such pressures may induce the formation of '*pseuedocommunites*' (Bannister, 2018, p. 126) that merely exist for the sake of participating in projects without any desire to make a difference to classroom instruction. We wanted to recruit teachers who would "act purposefully and constructively to direct their professional growth and contribute to the growth of their colleagues" (Calvert, 2016, p.4).

It is deemed that teachers in the projects participated in two-tiered PD communities of practice, the school community of practice and the project community of practice, as shown in Figure 1.

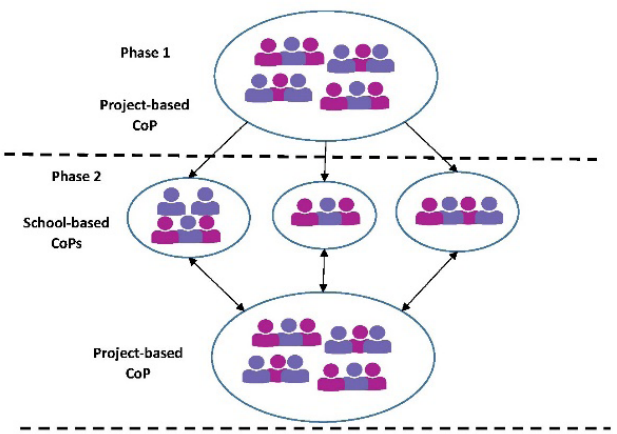

Figure 1. Two-tiered Communities of practice

In both communities, teachers were mutually engaged in activities (developing classroom tasks, co-planning instruction, critiquing, creating exemplars for fellow teachers in the fraternity), held together by their joint enterprise. The joint enterprise for both the projects, EPMT-RC and EPMT-TfM, was to enhance their classroom instruction incorporating initiatives and addressing gaps of the school mathematics curriculum respectively. Teachers in the projects also had a shared repertoire of customs for practice. i.e., common meeting routines, the same intended school curriculum documents – syllabuses and textbooks, and a common school calendar that framed the phases of the projects. Detailed descriptions of the design of these projects, EPMT-RC and EPMT-TfM, are provided in Kaur (2009, 2011) and Kaur et al. (2017) respectively.

4. Effective continuing professional development - Teachers' voice

In a past publication (Kaur & Karsenty, 2020)

teachers voice from the EPMT-RC project have been presented. Therefore, in this paper I focus on the responses of three teachers who participated in the EPMT-TfM project to a set of prompts in their end of project survey. The responses of these three teachers (TA 1, TA 2 and TD 1) were selected as they were representative of the range of responses collected from the teachers who participated in the project. The first prompt seeks inputs on their learning journey in the project. The second seeks inputs on how working and learning as a team in their respective schools contributed towards their learning journey and the third seeks inputs on how did the project group meetings, during which teams of teachers from a school shared their work with their peers from the other schools, contributed towards their learning journey. Table 1 shows the responses to the first prompt.

From the responses of the three teachers, TA 1, TA 2 and TD 3, in Table 1, it is apparent that there were different aspects of their learning journeys. TA 1 tells us how the team participating from her school began their work. Their actions are cognizant of the considerations teachers always have with regards to the content and timelines within the overall plan of the curriculum development at respective grade levels. Deciding not to disrupt the planned curriculum of the school, they decided to enact their "experimental" lessons during the school break with groups of students. They adopted the approach as advocated by the project when integrating their new knowledge into classroom practice, through the three steps – plan your lesson, enact it and record it for review and possible revisions. It appears that the 'hands-on" work contributed towards fruitful learning. It may be said that the experience of Teacher TA 1, which is representative of several others who participated in the project shows that teachers' everyday work could be a source for their constructive CPD (Ball & Cohen, 1999). It is also evident that a community of practice at the school was emerging. They were mutually engaged in activities held together by their joint enterprise of enhancing their classroom instruction engaging learners in metacognitive activities whilst co-constructing mathematical ideas.

Table 1: Learning journey of teacher participants in the project

Prompt	Describe as completely as possible your learning journey in the project
TA 1	When I decided to participate in this project, our sec 3 team came together to discuss which topic would be suitable for us to embark on the metacognition journey. As we have to balance the syllabus and SOW, we decided to work on topics for the next semester of school (July till Nov). This gave us more time to work on the project. We then divided the work into mainly 3 components, lesson plan, video and editing and lastly teaching. Each of us focused on our area and we came together to discuss and refine our plans. The journey has been a fruitful one as being hands-on with the planning allows us to learn and grow. We looked through our lesson and video and used what we had learnt during the course to better enhance our lesson.
TA 2	It was a gruelling journey as the project spanned almost two years. Much time was spent on the project after school, as well as planning and crafting the lessons for the class. However, throughout the project, there were a lot of learning points and it helped me improve myself as a classroom teacher.
TD 1	My learning journey can be divided into three phases. In the first phase, through the seven workshops, I acquired a better understanding on performative task, knowledge building task, teacher noticing, metacognitive skills and strategies. I had to plan a hypothetical lesson. The discussion and feedback from colleagues and Professor X was very fruitful and fulfilling. In phase 2, I worked with my school team on a detailed lesson plan, infusing elements of metacognition. We sat down to select the task, discussed the prompting questions and possible answers that the students might give and refined the lesson plan. The lesson was carried out and video-typed. The team met and viewed the lesson and prepared our presentation for the project group sharing meeting. This was part of a four-step approach. The other schools used the four-lens noticing feedback framework to give feedback on our lesson. Following which, Professor X and Research Assistant Y, came to school and guided us on lesson narrative. In phase 3, we had the second round of sharing of lessons and finally I presented and shared with other schools in North zones 3 and 6. I have benefited and was able to use approaches in teacher noticing to reflect and improve on my lesson. I also acquired and was able to use some metacognitive strategies confidently now in my lessons.

The response of TA 2, representative of several others in the project, shows that the project was demanding. Teachers worked together after their teaching duties, acquiring new knowledge and infusing the knowledge into their classroom practice. It is commendable that teachers merited the abundance of learning points and the goal of "improve myself as a classroom teacher".

The response of TD 1, provides a glimpse of the three phases of the project succinctly. It illuminates the role of the 'knowledgeable others' – Professor X and the Research Assistant, and scaffolds and tools like the four-step approach shown in Figure 2 and the four-lens noticing tool in Figure 3. Teachers whose responses mirrored that of TD 1, affirmed that the scaffolds, tools and new knowledge expounded during the CPD sessions have an impact on their classroom practice.

Table 2 shows the responses of the three teachers, TA 1, TA 2 and TD1 with regard to the contribution of working as a team in their respective schools. In a way it may be said that these responses reflect how the school-based communities of practice emerged and in the process of emergence supported the learning of each other. TA 1, TA 2 explicitly while TD 1 implicitly acknowledge that each individual brought to the team their respective strengths and weaknesses. By harnessing the strengths, team spirit fueled the leveling up of individual teaching competencies. It is apparent that the sum total of their learning exceeded the knowledge of individuals at the onset of their participation in the project.

Table 3 presents the responses of Teachers, TA1, TA 2 and TD 1, regarding the takeaways from being a part of the project-based community of practice. During the whole group session meetings, teachers shared knowledge providing opportunities for each other to appreciate aspects

1. Plan and write a detailed plan of the lesson.
2. Enact and video-record the lesson.
3. Watch the recorded lesson, compare it with the lesson plan and write the lesson narrative detailing the shortcomings and what the team would do differently the next time. A set of prompts were provided by the research team to guide the writing of the lesson narrative. The prompts were as follows:
   - Were the lesson objectives achieved? Was there any mismatch/deviation between the planned and enacted?
   - Were the mathematical tasks of knowledge-building type? How were the tasks enacted? Did they achieve the purpose they were intended for?
   - What were the metacognitive strategies that were developed? How were they developed? What challenges did the teacher encounter in developing them?
   - Did the teacher have any guiding mathematical norms that shaped the classroom discourse?
   - Did the teacher have any guiding socio-mathematical norms that shaped the classroom interactions between the students, and also teacher-student?
   - What was the sequence of activities during the lessons? [e.g. teacher talk (demonstration), seat work, discussion/teacher talk (instructions), group-work, student presentations, whole class discussion, etc….]
   - What was student engagement like during the lesson? [passive, active, problem solving, explaining, problem posing, etc….]
   - Did the students say anything about the lesson? How similar or different it was from the teacher's normal lesson?
   - Would the teacher rate the lesson as one that is taught for metacognition?
4. Write a reflection about the learning journey of the teacher's learning. Every member should do this individually, subsequently meet as a group and share with each other the reflections. The journal prompt was "Describe in detail your learning journey during the planning, enacting and reviewing of your team's lesson that was carried out with the goal of teaching for metacognition".

Figure 2. The four-step approach

<table>
<tr><td colspan="2">Teacher Noticing
You may use the following prompts to guide you in viewing the video record through the four lenses. The prompts are adopted from McDuffie et al. (2014).</td></tr>
<tr><td>Teaching Lens
▪ How does the teacher elicit students' thinking and respond?
• What opportunities does the teacher create for diverse learners to communicate their mathematical thinking – show what they know?
• How does the teacher implement the task in a way that maintains or changes the cognitive demand?
• What resources and knowledge does the teacher use/draw upon to support students' math understanding?</td><td>Learning Lens
▪ What specific math understandings and/or confusions are indicated in students' work, talk, and/or behaviour?
• How do students communicate what their understandings and sense making of others' thinking?
• In what ways does student engagement reflect conceptual and/or procedural learning?
• What resources or knowledge do students draw upon to understand and solve the math task?</td></tr>
<tr><td>Task Lens
▪ What is the nature of the task/s used in the lesson?
• What makes this a good and/or problematic task? How could it be improved? What is / are the central math idea/s in this task?
• How does the task make thinking visible?
• What resources or knowledge does this task activate and / or connect to?</td><td>Power & Participation Lens
▪ Who participates?
▪ Does the classroom culture value and encourage most students to speak, only a few, or only the teacher?
▪ Where does the majority of the math "work" take place in the classroom?
• Who holds authority for knowing mathematics? Do some students hold more status than others?
• What evidence indicates that differences in approaches and perspectives are/are not respected and valued?</td></tr>
</table>

Figure 3. The four-lens noticing guide

Table 2: Working and learning as a team in school

Prompt	How did working and learning as a team in your school help you in your learning journey?
TA 1	Each teacher has their strengths and weakness. Each also has a different level of experience teaching different classes and streams. Through the collaboration, we are able to share our knowledge and expertise to complement each other. It was a very good experience working as a team which forges our team spirit and level up our own teaching competencies.
TA 2	Working as a team helped generate more ideas than working as an individual. As our team consisted teachers of different levels of experience, it also helped the more experienced teachers impart knowledge and advice to the newer teachers. I personally have gained a lot of invaluable knowledge through working as a team.
TD 1	We shared our thoughts and bounced off ideas and discussed on how to develop the lesson on teaching metacognition effectively. I learnt new knowledge and good teaching practices from their experiences and knowledge.

Table 3: Learning from other schools in the project

Prompt	How did the large group (whole project group) sharing help you in your learning journey?
TA 1	Through the sharing sessions, I can learn from other schools on their approach and strategies. Other schools have covered on strategies that we have not done and also showed us how the same strategies can be applied in a different or even better way. As we are unable to cover all the metacognitive strategies, it is a good platform for us to learn more of the other strategies being put into action. We can then have a better idea of how to implement the strategies in our future lessons.

Prompt	How did the large group (whole project group) sharing help you in your learning journey?
TA 2	It helped me see things from other people's perspectives, as well as learn how other schools conduct their lessons based on the profiles and needs of their students.
TD 1	It was an enriching journey as we shared our knowledge and lesson ideas. I also have a better understanding of the mathematical norms and socio-mathematical norms in other schools. It was also an opportunity to learn from one another and in turn, looked into our learning and practices. The feedback and suggestions using the four lenses from the large group during the sharing meeting were sincere and constructive.

of new knowledge acquired during the first phase of the project that they did not infuse in their instructional practice during phase two of the project. As mentioned by TA2 and TD1 there were also opportunities to appreciate perspectives on how instruction is paired with profiles of students and, the mathematical norms and socio-mathematical norms in schools other than their own respectively. It is also apparent that during such whole group session meetings, the critique from peers was constructive and sincere and TD1 notes that the tool (shown in Figure 3) facilitated it. Such safe spaces are a hallmark of communities of practice as members are mutually engaged in activities held by their joint enterprise and a shared repertoire of customs for practice.

5. Empowering mathematics teachers to partake in continuing professional development

Two decades ago, Scott (2000) articulated that development activities should meet the needs of the school and teachers, be team-based and on-site and expert resources may be needed but schools must steer their developmental trajectories. The hybrid model of CPD has proven to not only steer in the direction of Scott's vision for building a team of high-quality teachers but also to empower them to take charge of their learning whilst situated in their professional communities of practice. The five critical features of the model content focus, coherence, duration, active learning and collective participation ensure that teachers **Learn** (Acquisition and co-construction of knowledge), **Apply** (integrate new knowledge into classroom practice) and **Teach** (develop fellow teachers nationally and/or internationally) whilst partaking in CPD.

This model of CPD also affords teachers to be agents of change (See, Kaur (2015)). Following participation in the EPMT-RC project, teachers from two schools were able to enlarge their community of practice and scale up the intervention school-wide. A bottom-up approach was adopted in the scaling of the intervention. A study of the phenomena in the two schools showed that the impact of the professional development project on student learning enthused other teachers in the schools to join those who had participated in the project, thereby enlarging the communities of practices in the respective schools. The activities of these communities of practice centered on the needs of the teachers, namely, acquisition of new knowledge, use of the knowledge in their classrooms, and feedback on student learning. The activities were facilitated by the resources (Kaur & Yeap, 2009a; 2009b) for teachers produced by the professional development project, and the two main processes adopted by the communities of practice: teachers learning by teaching other teachers; and teachers learning by making their work public and having it discussed and critiqued by their peers.

6. Limitations of the hybrid model and some recommendations

The model described in this paper was developed in the context of CPD of mathematics teachers in Singapore schools. The five critical features of the model illuminate aspects of PD that are worthy of emulation. Though it may not be possible to have the same context as in Singapore for CPD, it is possible to create synonymous models for use in other contexts. To do so, it is important to consider the following guides:

1. Content and coherence – what to teach and how to teach in response to the needs of the teachers.

2. Teacher agency - i.e., the capacity of

teachers to act purposefully and constructively to direct their professional growth and contribute to the growth of their colleagues.

3. Space and time – teachers must have physical or virtual safe spaces to meet, explore, discuss, experiment, critique their joint enterprise/s.

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