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ORIGINAL ARTICLE

What matters? From a small scale to a school-wide intervention

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Abstract Following participation in a professional development 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 shows 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 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.

Keywords Professional development · Mathematics teachers · Scaling of PD · Bottom-up approach · Reasoning · Communication · Mathematical tasks

1 Introduction

The most common type of professional development (PD) in Singapore for mathematics teachers has been in-service courses of the type that focuses primarily on expanding teachers' repertoire of classroom activities or introduction to new initiatives of the Ministry of Education (MOE) with regards to curriculum implementation. These PD activities may be said to belong to what Matos et al. (2009) describe as a "training model of professional development" (p 167). They are conducted by specialist officers from the mathematics curriculum planning and development division of the MOE or academics from the National Institute of Education, the sole institute for teacher education in Singapore. These courses are conducted for about 3 h per day spanning four to ten consecutive days or days spread over some weeks. Almost always following the completion of such a 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.

Such in-service courses are also sometimes used for scaling up "interventions" that have produced favorable outcomes in experimental classes. In this context scaling up refers to increase in the number of teachers, and consequently classes, that take part in the administration of the intervention, the desired outcome of which is improved student learning. In such cases inevitably a top-down approach is adopted and this is a result of decisions taken by school leaders or Ministry of Education officials. Needless to say, this view of scaling up "interventions" is contrary to that of Roschelle et al. (2008). Hargreaves (1995) notes that these in-service courses are often ineffective as teachers are likely to reject knowledge and skill requirements when the requirements are imposed or encountered in the context of multiple, contradictory, and overwhelming innovations; and when PD is packaged in off-site courses or one-off workshops that are alien to the purposes and contexts of their work. Smylie (1989) found that teachers ranked direct classroom experience as their most important site for learning. Furthermore, for some teachers PD may not be an

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autonomous activity, that is, chosen by a teacher in search of better ways of knowing and teaching mathematics (Castle and Aichele 1994).

In Singapore, the school mathematics curriculum is reviewed every 6–10 years. Textbooks, which are key to the implementation of the curriculum, are also revised periodically but they appear to manifest the content more than the processes. In 2006, the school mathematics curriculum in Singapore was revised and the scope of processes in the curriculum expanded to include reasoning and communication (MOE 2006a, b). A study conducted in the US by the American Institute for Research (AIR) found that textbooks in Singapore were focused on practice exercises that emphasize procedural knowledge but lacked emphasis on reasoning and communication which facilitate higher order thinking skills (Ginsburg et al. 2005). This study provided a much-needed outsider's perspective on the quality of curriculum materials that many teachers relied on for their teaching. Kaur et al. (2005) in their work with competent mathematics teachers in Singapore, found that the 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) to those available in the textbook used by the school and that these tasks were not suitable to engage students in reasoning (logical, deductive or inductive) and communication (explaining the process/thinking either during oral presentations or in writing). Furthermore, they found that teachers did not make explicit the need to understand but rather placed emphasis on procedural knowledge, that is, to remember algorithms and use them correctly to pass tests and examinations.

The 2006 revision of the curriculum and the research findings of Ginsburg et al. (2005) and Kaur et al. (2005) led the author of this paper and her colleague, Yeap, to conceptualize a project that would firstly provide teachers with the know-how of tasks that are suitable for engaging students in reasoning and communication and secondly support teachers in implementing their new knowledge in their classrooms. This project, known as Enhancing the Pedagogy of Mathematics Teachers (EPMT) (Kaur 2011) was carried out in 10 Singapore schools for 2 years. It was the first of its kind in Singapore schools and teacher participants of the project hailed it as a highly appropriate PD model for their learning. The EPMT project is described in detail in Sect. 3 of this paper.

Following participation in the EPMT project teachers from two schools were able to enlarge their community of practice and scale up the intervention school-wide. The experts, teachers who had participated in the EPMT project, were able to enlarge their school-based community of practice subsequently from four teachers each to 18 in the first school (primary) and 12 in the second school (secondary). Therefore it may be said that scaling up of an intervention had taken place and the approach was bottom-up. In the context of this paper, scaling up of an intervention refers to the growth in the number of teachers participating in the intervention, and bottom-up approach refers to teachers making decisions about their needs and working with fellow teachers, in this case in a school, to engage in professional development. The author of this paper, who was the university scholar and participated in the EPMT project, studied the phenomena in the two schools and here attempts to answer the following main question:

- How did the experts enlarge their community of practice and scale up the intervention school-wide? What factors helped them to do so?

2 Review of literature

In this section, relevant literature related to successful professional development activities, sustainable professional development programs and scaling up of professional development programs is reviewed. In the context of the paper, effective PD programs refer to those that impact teacher learning and consequently improve pupil learning. Also, beliefs refer to acceptance that something exists or is true without question of proof.

2.1 Successful professional development activities

High quality and effective professional development programs have been found to have a purpose as teachers are involved in shaping the foci of the program so that it is related to their school work (Clarke 1994; Hawley and Valli 1999; Elmore 2002). These PD programs are part of coherent programs of teacher learning and development that support their instructional activities at school, such as adoption of new standards (Stiff 2002; Desimone 2009) and focus on how to teach and what to teach—the substance and the subject matter—is key (Stiff 2002; Desimone 2009). Lipowsky and Rzejak cited in Maaß and Artique (2013) noted that teachers viewed professional development initiatives as effective if they had clear relevance to their day-to-day teaching and the programs had a clear focus on specific aspects of teaching or facilitation of student learning. Ball and Cohen (1999) have argued that "teachers' everyday work could become a source of constructive PD" (p. 6) through the development of a curriculum for professional learning that is grounded in the tasks, questions, and problems of practice.

Such programs include training, practice and feedback, and follow-up activities (Abdal-Haqq 1995). Ball (1996) claimed that the "most effective professional development model is thought to involve follow-up activities, usually in the form of long-term support, coaching in teachers' classrooms, or on-going interactions with colleagues" (pp. 501–502). Effective PD programs are sustained (Clarke 1994; Abdal-Haqq 1995; Hawley and Valli 1999; Elmore 2002; Stiff 2002; Borasi and Fonzi 2002; Desimone 2009) and embedded in teacher work (Clarke 1994; Abdal-Haqq 1995; Hawley and Valli 1999; Carpenter et al. 1999; Elmore 2002). Lipowsky and Rzejak noted that effective programs are also intensive, combining learning-off-job in courses with learning-on-job in school. Teachers learn best when observing, being observed, planning for classroom implementation, reviewing student work, and presenting, leading, and writing (Stiff 2002). Therefore opportunities for teachers to engage in active learning are certainly related to effectiveness of PD (Wilson and Berne 1999; Desimone 2009). They also value the exchange of experiences with colleagues (Lipowsky and Rezak). In addition, collective participation by teachers from the same school, grade or department allow for a powerful form of teacher learning through prolonged interaction and discourse (Wilson and Berne 1999; Desimone 2009; Stiff 2002). PD programs that foster collaboration have been found to be effective (Clarke 1994; Abdal-Haqq 1995; Hawley and Valli 1999; Elmore 2002; Borasi and Fonzi 2002).

2.2 Sustainable professional development programs

Research has shown that several factors may contribute to the sustainability of impact brought about by a professional development project (Zehetmeier and Krainer 2011; Lieberman and Wood 2001). Zehetmeier and Krainer (2011) noted that content, community, and context were three such factors. They found that for each of these factors a high level and balance was necessary in order to sustain the impact. Specifically, balance of subject-related action and reflection for content; individual and social activities, in particular fostering community building within and outside the professional development program, for community; and internal and external support for context. In their detailed study of a teacher who participated in a PD project they found that the teacher achieved impact on his knowledge, belief, and practice level and the impact was sustained. However, the impact was not sustained with regard to his colleagues' knowledge due to a lack of community building and networking. On the level of his colleagues' practice, "the impact regarding a culture of mutual feedback could not be sustained to a full extent, due to lacking relative advantage, need, and compatibility" (p. 883).

Lieberman and Wood (2001) found that professional development was sustained when teachers learnt by teaching other teachers and also by making their work pubic and open to critique. When the deficit mode of professional development, that is, teachers must only learn from experts, is reversed, teachers realize that they have knowledge that is valued, and can be shared with and built upon by other teachers. When teachers make their work public and open it for discussion and critique by their peers they come to understand that learning from one another involves having the courage to go public with their own teaching practices. They find that their peers can help them clarify aspects of their teaching and provide perspectives that they lacked. Having to switch roles between a presenter and member of the audience helps them overcome some of their initial apprehensions of making their work public.

2.3 Scaling up of professional development programs

How professional development programs scale up is often complex and closely related to the nature of the programs. Adler and Jaworski (2009) note that scaling up of programs is associated with the practicality of the program within different contextual settings. Programs that have the potential of scaling up should be tolerant as they will be implemented in different contexts (Roschelle et al. 2008; Maaß and Artique 2013). Thompson and William (2008) recommend a "tight but loose" framework for teachers' professional development with a tight adherence to central design principles and flexibility in regard to the needs, resources, and constraints occurring in a school context. The process of scaling may be top-down or bottom-up. Top-down approaches assume that the process is linear and the intended innovation is coherent with the classroom needs of teachers. In general, top-down planned changes are considered ineffective (Tirosh and Graeber 2003; Ponte et al. 1994); for example, professional development courses imposed on teachers are unlikely to succeed (Bishop and Denleg 2006).

As opposed to the top-down approach, changes in day-to-day teaching can be made from the bottom up (ground up) when groups of teachers work together to identify their needs, develop their own questions, and work on them together (Joubert and Sutherland 2009). Given the importance that context plays in teachers' work, particularly in professional development programs (e.g. Franke et al. 2001), the EPMT project situated learning and integration of new knowledge in teachers' classrooms (Kaur 2011). Matos et al. (2009) noted that in teacher professional development learning should be not be defined as the acquisition of knowledge of a propositional nature, but rather be conceptualized as being situated in forms of co-participation in the practices of teachers. Teachers participating in such learning may be said to belong to a community of practice (CoP) (Lave and Wenger 1991). Such a community does not exist when a group of teachers from several schools are interacting in a given setting such as attending a series of seminars or workshops, nor with groups of teachers in the same school who are teaching the same subject or year level but do not have mutual relationship and shared goals.

According to Wenger (1998), a CoP is a group of persons sharing the same practice. It has three key features: the members of a community of practice have a mutual enterprise; a shared commitment; and a common repertoire. This repertoire can contain material objects and stories that are shared by members of the community. By virtue of the design of the EPMT project, with at least four teachers per school voluntarily participating in it with a shared set of goals and commitment to one another, within each school the conditions were favorable for the development of a community of practice. Furthermore, as participants of the project the teachers also had a shared sense of accountability towards the work of the community, in this case the learning facilitated by the project. Contemporary socio-cultural theory of learning acknowledges that learning involves increasing participation in a CoP composed of experts and novices (Lave and Wenger 1991). So, while the teachers were participating in the project they were the novices and the university scholars were the experts; but subsequently as communities of practice at the school level enlarged, the experts were the teachers who had participated in the EPMT project and the new-comers were the novices.

Gueudet et al. (2013) caution that teachers working together on resources may sometimes not be a CoP. Rather they could be mere collectives. Gueudet et al. emphasize that advantageous conditions in terms of material provisions or time allocations are not enough to engage a dynamic towards a CoP. In addition, engaging such a dynamic requires teachers to work on common resources and to share professional knowledge and beliefs about the teaching of mathematics. In their study they claim that turning collectives into communities requires the "development of a synergy between teachers and resources" (p. 1014) and that this may be facilitated by material conditions such as common meeting times for teachers to work on shared tasks with the support of external agents such as university scholars or experts in the field.

Rogers (2003) highlights that the diffusion of an innovation depends on a few characteristics, namely relative advantage, compatibility, complexity, trialability, and observability. Given the competing tasks demanding teachers' time, relative advantage refers to the perceived advantage of the innovation compared with other tasks while compatibility refers to how compatible the innovation is with the needs of the teachers. Complexity refers to teachers' perception of how difficult the innovation is to be understood or used. Trialability denotes the opportunity for participating teachers to experiment and test the innovation. Observability refers to the visibility of the innovation to other persons, such as colleagues, parents or school leaders. Fullan (2001) describes similar characteristics vis-a-vis need, clarity, complexity, quality, and practicality that impact the diffusion of an innovation.

2.4 Summary

From the above review of literature it is apparent that effective PD activities do have common characteristics. Some of these characteristics are purpose, coherence, relevance, active learning, collective participation, and duration. Several factors may also contribute towards the sustainability of the impact brought about by a PD program. Some of these factors relate to the content, community, context, and learning process of participants of the program. The nature of a PD program often impacts its scalability. Programs that are tolerant and robust but yet flexible may be scalable. Furthermore, diffusion of an innovation depends on several of its characteristics, some of which are need, relative advantage, clarity, compatibility, quality, practicality, complexity, trialability and observability. Both top-down and bottom-up approaches may be adopted for scaling up interventions through PD programs. The community factor in PD programs may result in the formation of collectives or CoPs.

3 The EPMT project

Forty teachers, 22 from five secondary schools and 18 from five primary schools, participated in the project. The aims of the EPMT project were three fold. The first was to provide teachers with training on how to craft suitable learning tasks that engage students in reasoning and communication and teach for understanding during mathematics lessons. The second was to facilitate teachers' work (practice and feedback) at the school level by assigning them activities to carry out together with their fellow teachers who were also in the project. The third was to enthuse and support teachers to contribute towards the development of fellow mathematics teachers in Singapore.

The conceptual framework of the EPMT project draws on research findings, specifically the characteristics of effective PD programs. The project had five significant features, namely:

3.1 Content focus

The project was focussed on what to teach and how to teach (Stiff 2002; Desimone 2009). It was specific to the pedagogy of mathematics. This focus was similar to that of most in-service courses conducted for mathematics teachers in Singapore as the main objective of such courses is to introduce teachers to new initiatives that arise from curriculum revisions. As both primary and secondary teachers participated in the project, they worked with mathematical content that was appropriate for the grade levels of their students.

3.2 Coherence

The project was coherent with the needs of the teachers. It addressed the needs in the following ways:

– The revised mathematics curriculum of 2007 (Ministry of Education 2006a, b) placed emphasis on reasoning and communication in mathematics lessons. As textbook questions were judged to be inadequate for the purpose, there was a need for teachers to learn how to craft mathematical tasks that facilitate reasoning and communication during mathematics lessons.
– As teachers relied very heavily on textbooks for their daily work (Kaur 2010), there was a need for teachers to draw on textbook questions as starting points and craft tasks that would engage students in reasoning and communication.

The project supported the instructional activities of teachers at school, such as the adoption of new initiatives (Stiff 2002; Desimone 2009). 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 and Valli 1999; Carpenter et al. 1999; Elmore 2002).

3.3 Duration

The project spanned 2 years and comprised three phases. Teachers attended training workshops for a semester, followed by a semester of school-based work guided and monitored by the university scholars (PD providers), followed by another year (2 semesters) of self-directed school-based work. The duration of the project was significantly longer than most in-service courses that mathematics teachers usually attended.

3.4 Active learning

The project engaged teachers in active learning (Wilson and Berne 1999; Desimone 2009). It 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 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 ongoing interactions with colleagues.

3.5 Collective participation

In the project there was collective participation at two levels—school and project. At the school level, participation was by at least four teachers, with pairs of teachers teaching the same grade year and mathematics program. These teachers worked together during the training workshops and also at school when implementing their learning in their classrooms. At the project level, teachers also worked together building their knowledge by participating in sessions during which they critiqued their peers' work, and shared their experiences and difficulties encountered during the implementation of their newly gained knowledge.

4 Methodology

4.1 Subjects

Ten schools, five primary and five secondary, participated in the EPMT project. A year after the project was completed the researchers of the project emailed the teacher participants and sought information about how they were using the knowledge and skills they had acquired in the project and also if they were contributing towards the development of fellow teachers in their respective schools. The response rate to the email was 80 % and all claimed that they were using the knowledge and skills. However, only teachers in four schools said that they were contributing towards the development of fellow teachers. Out of these four schools, one was a primary school and three were secondary schools. Due to limited resources we only studied how the teachers were contributing towards the development of fellow teachers in two schools, one primary and one secondary. So we selected the primary school and from the three secondary schools we selected the one with the largest number of teachers, 12, in the enlarged school-based community of practice.

The subjects of the research reported in this paper were from the two schools, P1 (primary school) and S2 (secondary school), that participated in the EPMT project follow-up study. In P1, four teachers, P1T1, P1T2, P1T3, and P1T4, and in S2, four teachers S2T1, S2T2, S2T3, and S2T4, were the subjects interviewed as part of the study. They were randomly selected. Teachers P1T1, P1T2, S2T1, and S2T2 were participants of the EPMT project and later experts in the enlarged communities of practice in their respective schools, while teachers P1T3, P1T4, S2T3, and

S2T4 were novices in the enlarged communities of practice in their respective schools. All the teachers were female and had taught mathematics for at least 3 years at the time they became members of the communities of practice in their respective schools.

4.2 Sources of data

The qualitative data presented in this paper come from two data sources. The first is teacher interviews guided by a set of prompts. The interviews sought data from the expert teachers about why they continued with infusing their learning into their classrooms following participation in the EPMT project and how they contributed towards the learning of the novice teachers in their respective communities of practice. They also sought data from the novice teachers about why they joined the communities of practice of the expert teachers (participants of the EPMT project).

The four teachers (P1T1, P1T2, S2T1, and S2T2) who participated in the EPMT project, referred to as expert teachers in this study, were interviewed a year after the completion of the project. The interviews were guided by the following prompts:

Following the completion of the EPMT project,

- EP1: Have you continued using your knowledge and skills in your math lessons? If so, why have you done so?
- EP2: Has the community of practice nurtured by the EPMT project at your school remained active? If yes, what are the activities of the CoP?
- EP3: Have you contributed to the development of other colleagues in your school? If yes, how?

The other four teachers (P1T3, P1T4, S2T3, and S2T4) who were also interviewed were the novices in the enlarged communities of practice at the respective schools. The following prompts were used for the interviews:

- NP1: Why did you join your colleagues in school who are continuing with the work of the EPMT project?
- NP2: How are your "expert" colleagues helping you with construction and use of knowledge they have acquired from the EPMT project?

The second source of data is observation of a session in both schools during which the teachers worked together in their respective communities of practice. The observation was guided by a set of analytical questions and sought data on the objective of the working sessions and activities that took place during the sessions. The analytical questions were as follows:

- What was/were the objectives of the working session?
- What were the main activities that took place during the session?
- What was the main resource used?
- Who was/were leading the session?
- What were the "expert" teachers doing?
- What were the "novice" teachers doing?
- Was it apparent that a CoP existed?

The observation was carried out by two researchers. The researchers compiled their field notes independently.

4.3 Data analysis

The qualitative data were analyzed using qualitative analysis tools. Both deductive and inductive approaches were used to identify the categories or themes in the data collected. For the interview data we adopted an inductive approach and carried out content analysis (Weber 1990). Two researchers independently scanned through the interview scripts and listed inferences. This was done systematically for the "expert" and "novice" teacher data prompt by prompt. After completing the data for a prompt, the two researchers compared their inferences and resolved the differences through discussion. The inter-coder agreement ranged between 80 and 95 % for the interview data.

Table 1 shows examples of the responses of the four expert teachers, P1T1, P1T2, S2T1, and S2T2, to the interview prompts and the inferences drawn from the content analysis.

Table 2 shows examples of the responses of the four novice teachers, P1T3, P1T4, S2T3, and S2T4, to the interview prompts and the inferences drawn from the content analysis.

For the data on the observations of the sessions we adopted a deductive approach, known as framework analysis (Ritchie and Spencer 1994), as we had pre-determined themes and were looking for specific pieces of data in the observations. The two researchers who took field notes while observing the working sessions of the communities of practice in the respective schools subsequently met and discussed their responses to each of the questions. There was 100 % agreement between them about their findings for each of the analytical questions. In addition, the qualitative analysis was intra-case, as both schools formed a case (Berkowitz 1996). Therefore no attempt is made to compare and contrast the data of the primary school (P1) and the secondary school (S2).

Table 3 shows the analysis of the observations that is guided by a set of analytical questions.

Table 1 Content analysis of expert teacher interviews

Teacher	Response	Inferences
EP1: Have you continued using your knowledge and skills in your math lessons? If so, why have you done so?		
P1T1	Yes. I have changed my way of teaching mathematics somehow. Instead of going through corrections with pupils using chalk and talk, I learnt that pupils benefited most when they could discuss, communicate, and interact with their peers. Group communication helps to clear 'pupils' doubts in a non-teaching manner. Using strategies "what's wrong" and "what number makes sense?" are good as we get pupils to reflect and think through their solutions instead of telling them why they got the problems wrong. In this way, they will learn from their mistakes more effectively. Pupils also learn to understand that they can apply or relate the math concepts learnt to real-life situations. Hence, making math more interesting and meaningful for them. Their interest in math also increased due to the new teaching approach. They also do better in their written exercises	PD project: useful knowledge and skills PD sustained Pupil outcomes: meaningful and interesting lessons; improved learning
EP2: Has the community of practice nurtured by the EPMT project at your school remained active? If yes, what are the activities of the CoP?		
S2T2	The project helped us to work closely together in the school. We planned our lessons jointly and also gained each other's confidence. Our students and their learning got to be the focus. After the project ended, we continued to work as buddies enriching each other's lessons and sharing our "highs" and "lows"	CoP remained active Activities: joint lesson planning; review of lessons enacted—both strengths and weaknesses
EP3: Have you contributed to the development of other colleagues in your school? If yes, how?		
S2T1	When we were participating in the project, the four of us did periodic sharing with the other teachers in our math department about what we were doing and how the project impacted our classroom practice. This was facilitated by our head of the department as she found that while we advanced reasoning and communication in our lessons it also lead to improved learning. So after the project was completed, in my school our CoP was recognized as an activity for professional learning. So other teachers were free to join if they wished. Now we have another 8 teachers who have joined us. So during our professional learning sessions the four of us take turns to share with the group how we have engaged students in reasoning and communication in our math lessons–craft mathematical tasks using the strategies we learnt and how to implement the tasks. We use resources produced by the project–*Pathways to reasoning and communication in the secondary school mathematics classrooms* and *Pedagogy for engaged learning* as our resources	Contributed Used resource produced by the project to work through the strategies and craft tasks for use in lessons Shared experiences about students' engaged learning

5 Findings

In this section we present the findings of the teacher (expert and novice) interviews and the observation of a session in both schools during which the teachers worked together in their respective communities of practice.

5.1 Teacher interviews

5.1.1 Interviews of the expert teachers

From the content analysis, of the interview data of the "expert" teachers it was found that all the four teachers in the EPMT project have continued to use their knowledge and skills. They have done so as they found the knowledge and skills that they acquired in the project useful for making their mathematics lessons engaging, meaningful, interesting, and challenging. These lessons provided students with opportunities to work in groups, reason and communicate their thinking. They built confidence amongst the low-esteem students and improved the learning of all students.

The communities of practice of all four of the teachers in the EPMT project remained active even after a year following the completion of the project. The activities of the communities centered around crafting of mathematical tasks to facilitate reasoning and communication during their lessons, how the tasks may be used or were used and both affective and cognitive impact of the tasks on student learning.

All four of the teachers in the EPMT project have contributed towards the development of fellow colleagues in their schools. They, the "experts", have done so by working with the "novices" in their enlarged communities of practice. They used the EPMT resources and systematically introduced the strategies that they used for crafting mathematical tasks for reasoning and communication. They also shared their own learning in the project and their experiences of using the tasks in their lessons. Where possible

Table 2 Content analysis of novice teacher interviews

Teacher	Response	Inferences
NP1: Why did you join your colleagues in school who are continuing with the work of the EPMT project?		
P1T3	While my colleagues were participating in the EPMT project, I found that their classrooms were a buzz! Their pupils were talking, and having fun. When I gathered that pupil learning also improved, I was curious to learn from them how they were designing such lessons	Learn about strategies for engaging pupils in reasoning and communication Design lessons that would improve pupil learning
NP2: How are your "expert" colleagues helping you with construction and use of knowledge they have acquired from the EPMT project?		
S2T3	I am very lucky that my "expert" colleagues are very excited about sharing with us what they have experienced in the EPMT project. They use the resource book *Pathways to reasoning and communication in the secondary school mathematics classroom* as a reference and introduce one strategy at a time to us and show us how to craft tasks using the strategy. We work in small groups, craft tasks and present them for whole group discussion. All of us give feedback about the suitability of the task for specific instructional objectives. Our "expert" colleagues often show us tasks they have used in their lessons and the kind of student discussion the tasks facilitated	Use the EPMT resources and help us to – Work through the 'what' strategies one at a time. – Craft tasks using textbooks questions as starting points – Engage the whole group in giving feedback on tasks crafted Show tasks implemented and share the kind of discussion that resulted

they showed video clips of their lessons to show how they implemented the tasks. They also engaged in discussions with their peers to clarify the why, what, and how of lessons to facilitate learning mathematics via reasoning and communication.

5.1.2 Interviews of the novice teachers

The content analysis, of the interview data of the "novice" teachers showed that the four teachers joined the community of practice of their peers who were in the EPMT project because they wanted to learn how to use the EPMT resources and craft tasks to facilitate reasoning and communication in their mathematics lessons. They wanted to do so as student learning appeared to have improved in mathematics lessons of their EPMT project peers. In addition they were keen to learn how the tasks facilitated classroom interactions.

The "expert" colleagues helped the "novices" to make sense of the EPMT resources by working through the "what" strategies one at a time. They engaged them in using the strategies to craft tasks using textbook questions as starting points. They also facilitated critique of tasks crafted, so as to improve them. The "experts" shared their own experiences of using such tasks and the impact of the tasks on student learning. They also used video clips of their lessons to show how students respond to reasoning tasks.

5.2 Sessions of the CoP

5.2.1 Analysis of the sessions of the CoP

From the analysis of the two working sessions of the CoPs in the two respective schools it is apparent that the activities centred around three main needs of the teachers: the acquisition of new knowledge by the "novices", with the help of the "experts" in the communities; use of the knowledge to craft mathematical tasks for use in their lessons; and sharing feedback about the use of the tasks in lessons. The "experts" and "novices" both used the EPMT resource for building their knowledge and developing their own resources for use in their classrooms. It is also evident that both groups of teachers in the respective CoPs had a shared commitment, to improve the learning of their students. They also shared the same practice, did the same kinds of activities together, and had a common repertoire as they shared the mathematical tasks they crafted and shared stories about the use of them in their lessons.

6 Discussion

The data analyzed and presented in this paper are from two schools that participated in the EPMT project. The data were collected using interviews and observations. The interview prompts used by the researchers in the study may have had an impact on the responses articulated by the teachers and therefore represent their perceptions. Hence, based on the limitation posed by the quantity of the data and the inability to ensure that the data is comprehensive, generalizations cannot be made. However, it may be said that the data from the two schools that participated in this study does provide general insight into the possible factors that may support scaling up of school-based interventions. The research question that guided the study reported in this paper is:

> How did the "experts" enlarge their community of practice and scale up the intervention school-wide? What factors helped them to do so?

Table 3 Analysis of the observations of the working sessions

Analytical question 1	What was/were the objective/s of the working session?
School 1 (primary)	They were (1) to introduce to the novices the strategy: "What's the question if you know the answer?", (2) work in groups and craft mathematical tasks using the strategy, and (3) present and discuss the tasks crafted
School 2 (secondary)	It was to share experiences of using the strategy "what's wrong" in lessons
Analytical question 2	What were the main activities that took place during the session?
School 1 (primary)	They were: (1) Introducing "new knowledge" to the novices about a "what" strategy that may be used for crafting mathematical tasks to facilitate reasoning and communication during lessons, (2) Engaging in hands-on work, in groups, to craft mathematical tasks using the strategy using textbook questions as starting points, and (3) Presenting the tasks crafted and discussing them for possible refinements
School 2 (secondary)	They were (1) Presentation of "what's wrong" tasks used by teachers in their lessons, (2) Sharing video record of a lesson on the "what's wrong" strategy by one of the teachers, and (3) Discussion of what works or may not in lessons where such tasks are used
Analytical question 3	What was the main resource used?
School 1 (primary)	The EPMT resource: pathways to reasoning and communication in the primary school mathematics classroom. Textbooks used by the teachers for their instructional needs
School 2 (secondary)	Samples of tasks used by the teachers and a video record of one teacher's lesson
Analytical question 4	Who was/were leading the session?
School 1 (primary)	Both the "expert" and "novice" teachers
School 2 (secondary)	Both the "expert" and "novice" teachers
Analytical question 5	What were the "expert" teachers doing?
School 1 (primary)	They were leading the session to introduce the (1) "new knowledge", (2) crafting tasks alongside the "novices", and (3) presenting tasks and participating in the discussion on how to improve them
School 2 (secondary)	They were (1) presenting and sharing with colleagues their experiences of using the tasks, (2) viewing the video-recorded lesson, and (3) discussing the lesson for possible improvements so that student learning may be further enhanced
Analytical question 6	What were the "novice" teachers doing?
School 1 (primary)	They were (1) crafting tasks alongside the 'experts' and (2) presenting tasks and participating in the discussion on how to improve them
School 2 (secondary)	They were (1) presenting and sharing with colleagues their experiences of using the tasks, (2) viewing the video-recorded lesson, and (3) discussing the lesson for possible improvements so that student learning may be further enhanced
Analytical question 7	Was it apparent that a CoP existed?
School 1 (primary)	Yes, the members had shared goals. Though at times the "experts" were more knowledgeable they participated alongside the "novices" in all activities
School 2 (secondary)	Yes, the members had shared goals. Though at times the "experts" were more knowledgeable they participated alongside the "novices" in all activities

From the interview data of the "expert" teachers presented here it is apparent that the "experts" who were participants of the EPMT project continued using their knowledge and skills in mathematics lessons following completion of the project to make their mathematics lessons engaging, meaningful, interesting, and challenging through providing students with opportunities to work in groups, reason, and communicate their thinking. In this way they also built confidence amongst the low-esteem students and improved the learning of all students. It may be said that the impact brought about by the EPMT professional development project was sustained. It appears that the subject-related action and reflection for content, which supports the finding of Zehetmeier and Krainer (2011), and clear relevance of the knowledge and skills that the project imparted on the participants, which also supports the finding of Lipowsky and Rzejak, for their day-to-day teaching of mathematics fuelled the sustainability of the PD project.

From the data it is also apparent that the communities of practice, facilitated by the EPMT project, in both the schools remained active even after a year following the completion of the project. This appears to signal that the EPMT project facilitated community building amongst participants and also internal support for context which impacted the sustainability of the PD program. These findings are coherent with that of Zehetmeier and Krainer (2011) and also that of Clarke (1994), Abdal-Haqq (1995), Hawley and Valli (1999), Elmore (2002), and Borasi and Fonzi (2002) in that PD programs that foster collaboration have been found to be effective.

It is also apparent that the "experts" continued with community-building efforts and enlarged their respective communities of practice. They did so by working with the "novices" who joined their communities of practice. It appears that the main reason that community-building was fostered within the EPMT project initially and later beyond the project appears to be the need for support to improve student learning. This appears to be the community and also the internal and external support for context aspects that Zehetmeier and Krainer (2011) found in their research as factors that contribute to the sustainability of professional development programs.

From the interview data of the "novices" it is also apparent that the main reason why the "novices" wanted to learn from the "experts" the knowledge and skills they had acquired while participating in the EPMT project was because they found that student learning appeared to have improved in the mathematics lessons of their peers. The "experts" helped the "novices" to make sense of the EPMT resources by working through the "what" strategies one at a time. They engaged the "novices" in using the strategies to craft tasks using textbook questions as starting points. They also facilitated critiques of tasks crafted, so as to improve them. The "experts" shared their own experiences of using such tasks and the impact of the tasks on student learning. They also used video clips of their lessons to show how students respond to reasoning tasks. It is apparent from the activities that the "experts" engaged the "novices" in during their working sessions that there was a "tight but loose", as noted by Thompson and William (2008), framework adopted for professional development. There was a tight adherence to the central design principles of the EPMT project but certainly flexibility in regard to the needs of the teachers. The resource books produced by the EPMT project facilitated the adherence to the central design principles of the project.

The data from the two working sessions of the CoPs in the respective schools show that the activities of the CoPs centered on the needs of the teachers, mainly acquisition of new knowledge, use of the knowledge, and feedback about how the knowledge impacted student learning. The activities were facilitated by the resource for teachers produced by the EPMT professional development project, and mainly two processes adopted by the CoPs. These processes were teachers learning by teaching other teachers, and teachers learning by making their work public and having it discussed and critiqued by their peers. Lieberman and Wood (2001) found that professional development was sustained when these processes were adopted for learning by teachers. It was also apparent that teacher learning was not acquisition of knowledge of a propositional nature but rather situated in the co-participation of teachers to improve their practices. This supports Matos et al.'s (2009) finding about the nature of teacher professional development learning.

It is also apparent from the data of the two working sessions of the CoPs in the two respective schools that both groups of teachers in the CoPs had a shared commitment to improve the learning of their students. They also shared the same practice, did the same kinds of activities together, and had a common repertoire as they shared the mathematical tasks they crafted and shared stories about the use of them in their lessons. From the data it is apparent that the teachers were working together truly in the spirit of a CoP (Wenger 1998) and not merely as a collective (Gueudet et al. 2013).

From the findings of the study reported in this paper it may be said that the "experts" who were participants of the EPMT project were able to scale up the professional development program in their respective schools as the knowledge and skills that the project helped the teachers to develop:

1. Had a relative advantage for the teachers
2. Was compatible with the needs of the teachers
3. Could be experimented in their lessons
4. Was visible to others when student learning improved.

The above findings reinforce that of Rogers (2003) and Fullan (2001) about the diffusion of an innovation, in this case the intervention facilitated by the EPMT project. It is also apparent from the data presented in this paper that a bottom-up or ground-up approach facilitated the scaling up of the intervention. The group of "novice" teachers in each of the two schools identified their needs and joined the CoPs of the "expert" teachers in their respective schools and through the professional development that took place in the CoPs scaled up the intervention facilitated by the EPMT project.

7 Concluding remarks

The small-scale school-based intervention which resulted from the participation of four teachers in a professional development project (EPMT) in each of the two schools was scaled up in the respective schools by the teachers. The EPMT project was a hybrid of the training model of PD and sustained support for integration of knowledge gained from the PD into the practice of teachers. In the two schools, following completion of the project the teachers sustained their professional development through continued participation in their respective CoPs. They also enlarged their CoPs, and contributed to the learning of their peers. All this was possible as the activities of the CoPs led to improved student learning.

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