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Diverse Pathways for Life-long Teacher Professional Development

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Abstract

Teaching has become increasingly more complex in recent years. All over the world, education reforms demand that teachers teach contents new to them, inculcate 21st century competencies among their students, use interactive, student-centred pedagogies that may not match the predominant cultural norms, embed high technologies to suit students who are digital natives, and so on. To cope with these new responsibilities and teaching strategies, teachers must become life-long learners to regularly upgrade their competencies and change their mind-set such that whatever one is already doing well now can be further improved on. Many pathways in teacher professional development can be created to help them do so. This talk will discuss four pathways: coherent transition from pre-service training to in-service education, inquiry into personal practices through participation in education research, use of locally validated materials and practices, and building communities for mutual support such as lesson study. Practices from Singapore mathematics teacher education will be cited to illustrate these diverse pathways and seven reflection tasks are included to stimulate international discussion of critical issues about teacher professional development for mutual benefits.

1. Introduction: Complexity of Teaching and Needs for Life-long Learning

Teaching has become increasingly more complex in recent years. All over the world, education reforms demand that teachers

- teach contents new to them,
- inculcate 21st century competencies among their students,
- use interactive, student-centred pedagogies that may not match the predominant cultural norms, for example, Eastern teachers are expected to be skilled performers who can explain complex contents clearly and with enthusiasm, whereas Western

teachers are valued for being innovative in their teaching (Stevenson & Stigler, 1992), and

- embed sophisticated information technology tools such as subject-specific software and social networking (blog, wiki etc.) in lessons to suit students who are digital natives.

To cope with these new responsibilities and teaching strategies, teachers must become life-long learners to regularly upgrade their competencies and change their mind-set such that whatever one is already doing well now can be further improved on. This will lead to higher level of teacher quality.

The National Centre for Excellence in Teaching Mathematics (NCETM, 2009) in the United Kingdom stated that continuing professional development "for mathematics teachers should stimulate teachers to re-think, to experiment, to make fresh distinctions and to probe those distinctions to explore how they are informative in enabling choices related to teaching and learning" (p. 14). Although the teachers have to do the learning themselves, teacher educators and policy-makers must provide the appropriate pathways for this to happen. In this talk, I will share my experiences working as a mathematics teacher educator in three countries, namely Malaysia, Australia, and Singapore over the past three decades. I believe that some of these ideas can apply to some extent to science teachers as well. However, this is not a comprehensive review of quality professional development in either mathematics or science teacher education in Singapore or any other education systems.

First, let me outline several principles for teacher professional development (TPD) because these principles can be used to justify current practices and to suggest new pathways to promote teacher learning.

2. Principles of Teacher Professional Development

Several important principles, or loosely called "standards", for TPD in general and mathematics education in particular, have been discussed in the literature, for examples, Advisory Committee on Mathematics Education (ACME, 2002); Clarke (1994/2007); Darling-Hammond (2006); Garet et al. (2011); Hattie (2012); Hill (2004); Loucks-Horsley, Stiles, Mundry, Love, and Hewson (2010); Timperley, Wilson, Barrar, and Fung (2007); Weiss and Pasley (2009). According to Holland (2005), TPD in the United States has moved from developing generic teaching skills in the 1960s to subject-specific pedagogies that examine teachers' subject matter knowledge, student learning, and curriculum materials. This shift is reflected in the many principles proclaiming how mathematics teachers can learn by:

- constructing meanings and reasoning in mathematics themselves, beyond being able to carry out routine computations;
- analysing examples of student misconceptions in mathematics and how to deal with them;

- gaining knowledge of how students learn in mathematics or science;
- experimenting with advanced teaching techniques and reflecting on their experiences through participation in education research;
- supporting one another in a community of practitioners such as lesson study that is evolved from Japanese practice or teacher research groups (*jiaoyanzu* 教研组) as practised in China;
- integrating theory, research, and practice to build a coherent personal teaching style.

In 2005, I proposed a set of five principles that can be used to design pre-service teacher training, based on research and writings by many teacher educators (Wong, 2005). These principles are: (1) Spiral and Developmental Principle, (2) Coherence Principle, (3) Activity Principle, (4) Local Relevance and Global Perspective Principle, and (5) Guidance and Constructivist Principle. These "training" principles may also be applicable for TPD in general; for example, principle (4) will be referred to below.

As a consequence of participating in different types of TPD activities, teachers are expected to gain new content knowledge and pedagogical content knowledge, master new strategies to deal with students' misconceptions and learning, develop new and more progressive beliefs and values toward teaching, engage in reflective activities, and contribute to the teaching profession through mutual support and socialisation. More senior teachers may become leaders and agents for changes in pedagogy, curriculum, and policies. Providing life-long TPD requires diverse pathways that build on the teaching experiences of the teachers and match their personal goals and school needs. Some of these pathways may be provided by the schools, while others require providers from outside the schools, in particular, teacher education institutions, teacher professional associations such as the Science Teacher Association of Thailand (STAT), the Association of Mathematics Educators[1] of Singapore, and the National Council of Teachers of Mathematics[2] in the United States, non-profit agencies, and commercial organisations.

Reflection 1: Which personal or academic principles of TPD do you subscribe to? Why?

3. Diverse Pathways of Teacher Professional Development

In this section, I will discuss four pathways of TPD, not in any particular order of importance or effectiveness. Practices from Singapore mathematics teacher education, in particular, those designed by teacher educators at the National Institute of Education (NIE), Singapore, will be used to illustrate these diverse pathways. Since context is an important factor affecting the effects of TPD, these pathways need to be amended in order to work in other countries. Readers are invited to consider to what extent these pathways are aligned with the principles mentioned above.

[1] http://math.nie.edu.sg/ame
[2] http://nctm.org

3.1. Coherent transition from pre-service training to in-service education

Teachers gain competencies progressively through a series of stages, from pre-service training to mentoring as newly qualified teachers (NQT) and eventually, for some outstanding teachers, to mastery and leadership. According to Fuller's Stages of Concern model (Fuller, Parson, & Watkins, 1973), teachers develop professionally when they tackle different types of concerns, beginning with concerns about "self" (e.g., How well do I teach?), then about "task" (e.g., How do I explain this to my class?), and finally about "impacts" (e.g., Do my students understand this?). Although these developmental stages are not necessarily universal, for example, the stages were found to occur differently among Brunei teachers (Wong, Nannestad, Veloo, & Lourdusamy, 1999), they are helpful in thinking about TPD within a developmental framework. This means that the transition from pre-service training to in-service education in diverse forms should be coherent and focused on specific, important issues.

At NIE Singapore, the outcomes of pre-service training of pre-service teachers are defined by a set of "Graduand Teacher Competencies" covering values, skills, and knowledge (NIE, 2009). These competencies are to be developed through generic education courses, domain-specific methodology courses, and content knowledge courses. These courses must be academically rigorous and aligned with international best practices and they must remain relevant to the school curriculum and practices so that after graduation, NIE pre-service teachers are ready to begin full-time teaching in the schools, without further examination and/or accreditation by other external agencies. These competencies are also relevant for in-service TPD. The "Enhanced Partnership Model" stresses the strong tripartite relationship between NIE, the Singapore Ministry of Education (MOE), and schools to ensure a coherent transition across different stages of TPD. This transition is made much smoother because NIE is the main provider of programs leading to higher qualifications in education (e.g., Masters of Education, Masters of Teaching, PhD in education), education leadership for heads of departments of school subjects (Management and Leadership in Schools), and instructional leadership for senior teachers (Senior Teachers Programme). In 2010, to streamline strategic planning of TPD activities and to provide systemic support, MOE established the Academy of Singapore Teachers (AST[3]), and this Academy also conducts the Structured Mentoring Programme (SMP) to support beginning teachers in their induction to the profession. The Maths Subject Chapter of AST aims to build teacher capacity, encourage pedagogy innovation, and facilitate research-informed practice to impact student learning. This AST setup is expected to further enhance the transition from pre-service to in-service education for Singapore teachers.

Reflection 2: Is your journey from pre-service training to in-service TPD a coherent one supported by the education system?

[3] http://www.academyofsingaporeteachers.moe.gov.sg/

3.2. Inquiry into personal practices through participation in education research

Teachers should be reflective practitioners rather than technical workers who carry out the teaching actions in a mechanical or routinized way. To achieve this high level goal, teachers should make inquiry into their own practices, and a systematic way to do so is for them to engage in education research as a form of TPD. This engagement can take place in three main ways:

a) undertake action research courses,
b) conduct action research individually or collaboratively in school-based teams, and
c) join a research team as active researchers.

3.2.1. Action research

Action research is widely proclaimed over the past few decades as a powerful form of TPD because reflection is its most crucial element. There are numerous books on how to conduct action research in general (Baumfield, Hall, & Wall, 2008; Hendricks, 2009; Koshy, 2010; Soh & Tan, 2008), but action research must combine research tools with domain-specific pedagogy in order to be effective. Hence, for mathematics teachers, it is important to study examples taken from mathematics education, and these include work by Artzt and Armour-Thomas (2002), Jensen (1992), Masingila (2006), and others. In Singapore, action research was introduced in the 1980s, became dormant in the 1990s, and then re-emerged in the 2000s with strong support from MOE. Action research projects at three different levels, namely individual, whole school, and zone, have been trialled. They are described below.

At the individual level, teachers may attend action research courses that are either generic or integrated with domain-specific pedagogy. These courses may include learning theories, and these theories can be used as the basis to generate hypotheses about classroom situations worthy of investigation and to interpret teachers' classroom experiences. The teachers then implement small-scale projects as part of the course assessment requirements. Later they may help their colleagues to conduct action research projects in their schools. This approach to build research capacity of teachers was given a boost when MOE in 2006 began to train selected teachers to serve as "research activists" in their schools. Their first attempt was to conduct studies related to the initiative called "Teach Less, Learn More", which was newly launched in 2004. This suggests using action research as a way to help teachers learn more about official education initiatives and test new ideas about teaching and learning as part of curriculum innovation. Their reports were compiled by Tan, Ee, Lee, and Lam (2007). Twenty nine projects were conducted, and they applied generic and well-known pedagogies such as Socratic questioning, problem-based learning, Understanding by Design (UbD), and journal writing to the teaching of languages, humanities, sciences (8 projects), and mathematics (only one project). The reports did not describe in detail the subject-specific pedagogies and the quality of student learning outcomes as they seem to focus on quantitative changes in traditional test scores and student attitudes between pre-intervention and post-intervention as well as feedback from students about the "new" teaching actions.

The whole school approach has been recommended as effective to bring about education changes within a particular school because it sets a common goal for the whole school and encourages all the teachers in the school to participate collaboratively to achieve it. It is also considered an effective strategy of TPD. An example is how teachers in Compassvale Secondary School in Singapore developed and completed 18 action research projects covering teaching and learning problems of their own choice under the guidance of an external consultant (Chew, 2006). There were three mathematics projects and the teaching actions dealt with the use of on-line resources, differentiated instruction using different worksheets of the same contents (e.g., step-by-step instructions, mind-maps, or self-discovery), and remediation activities conducted after school hours. The reports included similar research components found in those compiled in Tan et al. (2007) mentioned above.

Schools in Singapore are organized into four zones, and the superintendents in these zones often promote professional learning communities (PLCs) among teachers in the schools within each zone. Thus, the third level of action research involves a zone-based community of teachers conducting research about their school practices that share common issues across several schools. The North Zone, in particular, has been very active in promoting action research among its 91 primary and secondary schools under its School-Based Curriculum Communities of Practice (SBC-CoPs) program. The action research reports are published in its annual *Celebrating LEarning through Active Research (CLEAR)* series starting from 2005. Participating schools form action research teams that address similar teaching and learning issues and they experiment with "new" pedagogies under the guidance of external consultants. Most recently, five primary schools in the North Zone conducted action research projects that focused on the use of heuristics in mathematics problem solving. Their projects shared a common focus on heuristics but differed in the learning problems identified by the teachers, grade levels, and mathematics topics. To promote a community of learning among the participating teams, the teachers were required to present drafts of their project findings so that the other teams could provide feedback to help the presenting team improve its analysis and interpretation of the findings. Subsequently every team presented its findings and reflection of its journey of action research to teachers from the same zone at a mini-symposium.

In Singapore, pre-service teachers at NIE are not required to conduct education research as part of their pre-service training. Upon graduation, those who plan to enhance their teaching competence through action research may participate in the activities described above. For the past ten years, I have taught action research courses to primary and secondary school teachers and worked with a few action research teams. I find that Singapore teachers can quickly learn about research design and basic data analysis, but the following three aspects need further attention in order to reap the benefits of action research as a TPD activity.

First, Singapore teachers know about the main learning difficulties of the students whom they wish to help, but they need guidance to think of innovative, relevant instructional techniques to deal with these difficulties. For example, when lower primary pupils have difficulty

solving word problems that include words like “more” and “less”, the teachers tend to think of Polya’s 4-steps in broad terms but not reading and visualisation strategies that focus on the meanings of these problematic words in different word problem contexts. This suggests that carrying out action research per se is not effective in improving pedagogy to help students learn better, unless it is also coupled with experiences derived from working on pedagogies new to the teachers. Having them read about learning theories may be a helpful first step but it is found to be inadequate because most of the writings about theories require the ability to transfer theory into practice, which is lacking in many teachers. The “remedy” may not be deeper content knowledge as suggested by American researchers (e.g., AERA, 2005); instead, it is necessary to have the teachers widen their repertoire through working on specific teaching techniques in simulated or authentic classroom conditions, under the guidance of more capable teachers or teacher educators.

The second aspect, probably quite difficult to deal with, is the ability of teachers to reflect deeply about their own experiences of conducting the project using data collected about their own actions. To do so requires teachers to systematically collect data in the following three aspects:

a) *Behaviours:* their actions and interactions with students during the implementation of their project; for example, how long did they take to go through one cycle of metacognitive questions used during mathematics problem solving; did they become more competent in using the new technique after several attempts; how well had they followed the plan as intended and when modifications were made, what were they and why?
b) *Emotions:* their feelings during critical events of the lessons; for example, how did they feel when the students looked confused in lessons conducted using the new technique?
c) *Cognition:* what were they thinking about during critical events and did their reflections take into consideration significant learning theories?

Instead of focussing on their actions, many teachers tend to write about the “success” or “significance at 5% level” of their projects in terms of student scores in traditional paper-and-pencil tests. Within the Singapore education context, it is understandable that teachers want their students to have better scores after they have expended much time and effort to conduct the action research, but ignoring the critical step to reflect on their own actions based on evidence, they miss the opportunity to use it as a form of TPD. For example, of the 35 mathematics-related projects conducted in the past few years, only three explicitly included reflection of their personal experience of conducting their projects. None of them reported any data about their implementation and to what extent their implementation matched the plan. When teachers fail to use the action research project as an opportunity to review their own beliefs, assumptions, philosophies of teaching and so on, their work lacks what Inoue (2012) referred to as the *ironic* validity of action research because “self-growth and professional development take place when you … reflect on the source of the unexpected results” (pp. 169-170), and that source could come from systematic data collection.

The “reflection” parts of many action research reports are descriptive (e.g., I did this) rather than analytical, for example, to explain how one event leads to or is related to another. It is certainly important to be able to describe critical events in detail because this helps to develop mindfulness, but this can be deepened by assisting the teachers to relate the events to relevant theories, to look for plausible and different explanations of the events, and to design appropriate follow-up activities based on these personal deliberations. This can lead to new knowledge, although, unfortunately, knowledge creation is not commonly included as an important goal of action research.

The third aspect is that it is rare to find teachers who repeat the “cycle” of an action research project to fine-tune their pedagogy skills based on what has been learned from the first attempt. (Here, “cycle” does not refer to the “plan – act – collect data – reflect” cycle within a single project.) The spiral and developmental principle suggests that teachers must experiment with the same skills under different classroom conditions with different students before they gain the competency and confidence to make the techniques part of their repertoire in day-to-day teaching. Such replication, when carried out with evidence-based reflection, should contribute to the effectiveness of action research as a form of TPD.

3.2.2. Join research teams

Teachers can also gain research skills and new techniques by working in research teams as active collaborators rather than mere subjects of research conducted by others. NIE has several research centres[4], and two of them, the Centre for Research in Pedagogy and Practice (CRPP) and Learning Science Laboratory (LSL), have engaged teachers as active members in various research projects. They may contribute ideas for dealing with specific learning problems, alert team members about relevant classroom conditions that might impact on the research, carry out innovative teaching strategies, provide feedback about these strategies, and write papers about their experiences. These projects usually have theoretical backing, and the participating teachers will then gain knowledge about these theories, thereby helping them to make links between theory, practice, and research. Summaries of the numerous projects can be found in the NIE website. Research findings are also publicized in international journals, conferences, and the following three in-house publications:

a) *SingTeach* is an e-magazine that includes many reports written by teachers for teachers, from the vintage point of practitioners,
b) *NIE Research Brief Series* communicates findings to policy-makers, school leaders, and researchers, and
c) *ReED* (*Research in Education*) is a bulletin for sharing findings with the global community.

[4] http://www.nie.edu.sg/researchnie/research-centres

As an example, my colleague and I worked with four teachers on a small-scale project with the objective to train students to ask mathematics questions when they do not understand certain parts of the lessons (Wong & Quek, 2009). A set of student question cards was created to cover four significant types of mathematics questions: *meanings*, *methods*, *reasons*, and *applications*. Two primary and two secondary teachers participated in this project, and their active contributions included helping to write some of the mathematics questions and implementing the student questioning pedagogy in their own ways, which were more appropriate for the students they were teaching compared to merely following a uniform routine suggested by the researchers.

Reflection 3: What is your experience in using action research and participation in funded research to further your TPD in research and/or pedagogy?

3.3. Use of locally validated materials and practices

"Think globally, act locally" has become a popular catch phrase that emphasizes the interdependence of local and global factors that impact on many areas of practices and research, including education. Teacher educators in Singapore have generally relied on writings and research from English-speaking countries, especially Australia, England, and the United States, partly because many of them have gained their doctorate from these countries. Although these influences are still very strong in shaping TPD in Singapore, there is a gradual attempt in recent years to include Eastern perspectives to modulate Western theories and practices. Some mathematics educators in the Mathematics and Mathematics Education Academic Group at NIE have investigated best practices culled from the international literature and after local experimentation have developed materials and strategies that are now used in pre-service and in-service teacher training. They have published two resource books consisting of such locally validated materials (Lee & Lee, 2009a, 2009b), even though many activities in these books also have an international flavor. Both resource books are the products of several years of piloting and refinement. The chapters in these books deal with issues about the Singapore mathematics curriculum, theories of teaching and learning of mathematics, and ideas for teaching specific mathematics topics and processes. Two types of tutorial activities are included: (a) activities to be carried out by pre-service teachers to enable them to learn about mathematics instruction, and (b) activities that they can use in future lessons in the schools. Having pre-service teachers work through the second type of activities under the guidance of tutors will better prepare them to use these activities later on.

At first sight it might be puzzling to treat published materials as a *pathway* of TPD, but the underlying notion of this approach is to create a pathway that combines the best from the rest of the world with validated local practices. This global-local approach is particularly critical for NIE because being the sole teacher education in Singapore, it has no local "competitor" to benchmark against, thus striving for global standards is an important strategy for continual upgrading of the quality of its programs to produce competent teachers for the country.

At the systemic level, the most obvious infusion of locally developed materials and practices into Singapore mathematics instruction is the so-called "model drawing" approach (Kho, Yeo, & Lim, 2009; Ng & Lee, 2009). This is widely known internationally as a key feature of the so-called "Singapore Math", although this term is hardly used locally. A few years ago, the Mathematics Unit of MOE developed a set of tools called AlgeDisc and AlgeTools for the teaching of algebra. It is similar to the area approach of representing, expanding, and factorizing algebraic expressions (Leong et al., 2010). The most recent version of the Singapore mathematics curriculum includes learning experiences for teaching various topics. Many of these learning experiences are contributed by local teachers who have found them to "work" in their classrooms, and documenting these activities for the benefits of other teachers is a form of TPD for the teachers who have designed these activities. Including these local materials and practices in courses, workshops, and research will strengthen the relevance of TPD.

Reflection 4: To what extent have international (in particular Western) practices influenced your own TPD as well as TPD offered at your institute? Is there a need to produce locally validated materials for TPD? If so, how is this to be developed?

3.4. Building professional learning communities for mutual support

Communities of practice (CoPs), professional learning communities (PLCs) and other forms of professional networking have become a strong alternative to workshops, courses, and conferences offered for TPD because "they support opportunities for professional self-disclosure, reflection and growth in collaboration with colleagues (Yildirm, 2008, p. 235). As discussed above, action research at the zone level aims to promote PLCs among Singapore teachers. Learning circles and lesson study (Hart, Alston, & Murate, 2011) are other forms of PLCs. In recent years, lesson study has gained wide acceptance among Singapore schools. Many schools have set aside specific free slots called "white space" for teachers to conduct various activities related to lesson study, such as planning a lesson, conducting a research lesson, and debriefing after the research lesson is over. Examples of lesson study in Singapore can be found at *SingTeach*[5]. In one particular case (Choy, Quah, Tan & Toh, 2011), the teachers claimed that through lesson study they had "gained some important insights on preparing effective lessons" (p. 2). Some schools participate actively in lesson study within world-wide networking, for example, the World Association of Lesson Studies[6] and the APEC project on lesson study coordinated at Khon Kaen University[7]. Although many Singapore schools have conducted lesson studies, it is not known how many "cycles" of the refined research lessons have been implemented by the same team over an extended period of time. Furthermore, research is still lacking in Singapore on the more enduring impacts of this form of TPD on teacher learning and practices, and much less is known about its effects on student achievement in various school subjects. Indeed, as pointed out by Hart, Alston, and Murata (2011), "*research on lesson study* (original italics) is still in its infancy" (p. v).

[5] http://www.nie.edu.sg/newsroom/singteach-sepoct-lesson-study-singapore
[6] http://www.worldals.org/
[7] http://hrd.apecwiki.org/index.php/Lesson_Study

To further facilitate the implementation of PLCs in schools, MOE (2010) has produced a very comprehensive handbook on how to organize PLCs. It explains the benefits of PLC, the roles and responsibilities of team members, and an extensive collection of tools and templates, which can be used at different phases of PLCs. Despite such informative scaffolding, building a viable PLC within a single school or across schools is still a daunting endeavor with many challenges. Recent reports from the United States (Bay-Williams & Speer, 2012) have identified some of these challenges, such as time management, negotiation across different expertise and epistemologies, and support. Among the 22 reports compiled by Bay-Williams and Speer (2012), only two reports have documented sustainability of professional collaboration over a few years, and interestingly, both reports are about lesson study in mathematics. Thus, more study is needed to document how PLC projects can be sustained in order to reap its purported benefits to improve teaching and learning.

Reflection 5: What are your experiences of PLCs?

3.5. A smorgasbord of other pathways

Singapore teachers are entitled to 100 hours per year of paid-for TPD. Every school has a senior teacher who serves as a staff developer to help teachers plan their PD to match the individual needs of the teachers as well as the school's mission. Teachers often claim these hours through taking education courses, attending local and overseas conferences, and conducting sharing sessions about their own learning. However, teachers can also use these TPD hours to learn about matters not directly related to school teaching. It is believed that through such educative though not necessarily education experiences, the teachers can become better, for example in social skills and personal well-being.

Newly qualified teachers are also given organized school-based mentoring by senior teachers. They have lower workload to ensure that they have some time to learn about many non-teaching responsibilities.

In addition to the formal pathways enunciated above, there are informal pathways made available to teachers or created surreptitiously by the teachers themselves to help advance their practices. Research into such informal pathways is still lacking. A notable exception is the survey reported by Fan and Cheong (2003). They surveyed the sources of pedagogical knowledge among a representative sample of 73 mathematics teachers from six secondary schools, and found that the two most important sources were the teacher's own teaching experience and their informal exchanges with colleagues. This finding seems to resonate with an observation made by Feiman-Nemser (2001), that the effects of teacher education programs were weak compared to the influence of "teachers' own schooling and their on-the-job experience" (p.1014). A challenge for teachers is how to learn from such personal contacts. Essentially, being mindful of these opportunities is the first step towards capitalizing on such experiences.

Technologies have been proposed as an effective medium to provide innovative TPD that is more in tune with the digital natives who are now entering the teaching profession, for examples, use of multimedia cases (McGraw, Lynch, Koc, Budak, & Brown, 2007) and wiki (Sandifer, 2011). This could become the next trend of TPD for Singapore teachers, and research is needed to explore this latest possibility.

4. Professional Development of Teacher Educators

In a widely cited report on the world's best-performing school systems, the authors of the first McKinsey report (Barber & Mourshed, 2007) quoted a comment made by a South Korean policy-maker: "The quality of an education system cannot exceed the quality of its teachers" (p. 16). This may be generalized to teacher education as well: the quality of a teacher education program cannot exceed the qualifications of its faculty. NIE has taken note of this relationship and states in its document for teacher education for the 21st century that "21st century teachers call for 21st century teacher educators" (NIE, 2009, p. 25). Indeed, most of the teacher educators at NIE have school teaching experiences and hold a doctorate in education or the respective discipline areas.

An unusual practice at NIE is that mathematicians are also required to supervise practicum of secondary school pre-service teachers. Some of them have no teaching qualifications or school teaching. Thus, they have to learn about this education aspect of their responsibility. This is achieved by having senior faculty taking the mathematicians on practicum rounds to explain to them what are to be observed and discussed with the pre-service teachers and their school mentors. Over the years, under this form of professional development for mathematicians, many of them have become competent practicum supervisors.

However, teacher educators, as teachers' teachers, "occupy the pinnacle of a hierarchy of power and authority" in teacher education (Wong, 2001), and there are few studies about how they carry out the training provided to pre-service and in-service teachers, the impacts of their work, and how they develop professionally. Even (2008) noted that "there is almost no research on the education of mathematics teacher educators" (p. 57). Two recent pieces of work have attempted to fill this gap. First, the volume edited by Jaworski and Wood (2008) covers the development of mathematics teacher educators as professionals on their own rights. It is helpful to read about how several authors describe personal journeys of learning from research and working with school teachers on changing instructional approaches, but a systematic mapping of the trajectory of the professional development of teacher educators remains to be undertaken. This shows the complexity of the field of teacher education in general and mathematics teacher education in particular.

Second, under the aegis of the International Association for the Evaluation of Educational Achievement (IEA), 17 countries participated in a comparative study called Teacher Education and Development Study in Mathematics (TEDS-M) to investigate the training of primary and lower secondary future teachers in their countries. A unique feature of this study was a survey of the background, beliefs, and opportunities to learn provided by the courses

taught by the teacher educators of these future teachers (Tatto et al., 2012). Twenty five mathematics educators and mathematicians at NIE responded to the teacher educator questionnaire. They reported frequently asking future teachers to ask questions during class time and to participate in whole class discussions. However, these future teachers reported lower frequencies of these interactive learning experiences, suggesting a mismatch between perceptions of pre-service teachers and teacher educators. Further analyses of the Singapore and international data from the TEDS-M study will shed invaluable insights about the work of teacher educators.

Reflection 6: For teacher educators, think of one form of professional learning that works for you and to what extent it can be modified as a form of TPD for teachers whom you work with.

5. Concluding Remarks

If school teaching is complex, then educating future teachers to learn to teach and practising teachers to teach more effectively can be even more complex as more than one type of learning is involved. As pointed out by many teacher educators (e.g., Darling-Hammond & Richardson, 2009), one-shot workshops are not effective to help teachers acquire these complex skills. Although developing expertise in teaching may not need the 10 000 hours required for other professional expertise mentioned by Gladwell (2009), working through deliberate practice to acquire micro-teaching skills, obtaining meaningful feedback from students and colleagues, reflecting on evidence, refining practices, and so forth will take much more time than is normally available to most teachers. This is where school leaders and ministry policy-makers should design policies and provide support as well as motivation to require, not just encourage, teachers to engage in relevant, continuous professional development.

Both action research and lesson study are extended TPD activities requiring enormous amount of time and energy to plan the project, collect data, complete the analyses, meet with colleagues, and deal with many other unexpected events. Even though these activities can help teachers develop complex research skills, under the tremendous pressure to multi-task in schools, however, it is not surprising that there are very few replications ("cycles") of these projects. It is not clear whether these projects have helped teachers to master new teaching strategies that they can sustain in daily teaching. In fact, effective pedagogy such as wait-time and the use of counter-examples in mathematics explanations is quite well-known, but, according to Leahy and Wiliam (2012), it takes time for teachers to learn and to integrate it into their current routines. They recommend that teachers begin their professional learning in "small steps" (p. 57).

It is crucial to recognize that TPD is a goal-directed activity, and there are many reasons for teachers to engage in TPD: monetary rewards based on improved performance, intrinsic motivation to do better in one's work, joy of learning, promotion, and career advancement. Singapore teachers can advance along three tracks: leadership, senior specialist, and teaching.

Hence, TPD must be consistent with the future career goal of the teachers, and the appointment of school-based staff developers may facilitate this match of goals and TPD.

The pathways described above are not to be taken as blueprints for other countries to follow because these pathways are products consequent on certain unique features of NIE, for example, it is the only teacher education institute in Singapore and it has particularly strong links with MOE and the schools, features that might not be present in other countries. Nevertheless, the examples and reflections given here may suggest alternatives for teacher educators in other countries. In this era of globalized education, borrowing and lending (Steiner-Khamsi & Waldow, 2012) of education ideas through international conferences like this one or comparative studies like TEDS-M will be beneficial to both the "borrowers" as well as the "lenders".

A final point may be in order. Teachers must take ownership of their own professional development. They should be mindful of their inborn gifts and develop them to fulfil their own personal call or mission as an education professional, be it to share their enthusiasm of doing mathematics or science with their students, to prepare them as good citizens for the future, to contribute to the education fraternity, to achieve other commendable goals for humankind, and so on. With such overarching goals in mind, different teacher professional development pathways can take on great significance for the life and growth of the teachers. These pathways should take teachers out of their comfort zone and inspire them to contemplate deeply about their personal call or mission. I sincerely wish all teacher educators and teachers success in achieving their unique call within the education vocation.

Reflection 7: What is your main take-away from this session?

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