Synthesis of Reviews on Teacher Professional Development in Sub-Saharan Africa With a Focus on Mathematics

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Table of contents

Acronyms

SSA	Sub-Saharan Africa
TPD	Teacher Professional Development
TPDL	Teacher Professional Development and Learning
CPDL	Continuous Professional Development and Learning
TVET	Technical and Vocational Education and Training
LMICs	Low and Middle-Income Countries
VHICs	Very High-Income Countries
TLMs	Teaching and Learning Materials
OER	Open Educational Resource
GITPD	Grounded Insights For Teacher Professional Development, in reference to: Haßler, B., Hennessy, S. & Hofmann, R. (2018). Sustaining and Scaling Pedagogic Innovation in Sub-Saharan Africa: Grounded Insights For Teacher Professional Development. Journal of Learning for Development, 5(1). Retrieved from http://jl4d.org/index.php/ejl4d/article/view/264.
DGT	Developing Great Teaching, in reference to: Cordingley, P., Higgins, S., Greany, T., Buckler, N., Coles-Jordan, D., Crisp, B., … Coe, R. (2015). *Developing Great Teaching: Lessons from the international*[1] *reviews into effective professional development*. Teacher Development Trust. Retrieved from https://tdtrust.org/about/dgt.
MESSA	Mathematics Education in Sub-Saharan Africa, in reference to: The World Bank Group. (2016). *Mathematics education in Sub-Saharan Africa: status, challenges, and opportunities (Vol. 2) : main report (English)* (No. ACS19117). Washington, DC. Retrieved from http://documents.worldbank.org/curated/en/538251476977591230/main-report.

[1] Note that the review was commissioned by a UK-based organisation; therefore, where DGT uses ‘international’ this is with reference to the UK, i.e., ‘international to the UK’.

1. Mathematics education in sub-Saharan Africa

This section reviews the state of mathematics education in sub-Saharan Africa (SSA). Many of the points made are equally applicable to general education (in secondary or primary) as well as to other subjects.

1.1. State of mathematics education in SSA

The educational issues in SSA have been known for decades: *"poorly-resourced schools; large classes; a curriculum hardly relevant to the daily lives of students; a lack of qualified teachers; and inadequate teacher education programs"* (Ottevanger, et al., 2007:13). While the issue of large classes is being addressed in some contexts, this has often been through unqualified teachers — the student numbers per qualified teacher remain high (GMR, 2014). The same applies to mathematics education in the region.

The post-2015-pre-2030 development agenda is focussing on raising the quality of teaching and learning in schools (UNESCO, 2014; Sustainable Development Goal 4), and, in particular, on supporting teacher learning (Westbrook, et al., 2013; Orr, et al., 2013; Moon, et al., 2013; and references therein). There is an increasing consensus that African teacher education needs to become more effective, and needs to focus on more effective and culturally appropriate pedagogical practices, both in the classroom and at the school level. There is also a consensus among African policymakers that high-quality mathematics and science education is important for a competitive labour force:

> *"However, science, mathematics and technology education (this includes ICT) at the level of basic education faces serious problems. These include inadequate infrastructure (equipment, multi-purpose classrooms) and shortages of relevant learning and teaching materials. Perhaps most importantly, there is a lack of properly trained teachers with a good mastery of the content and proper methodologies to transfer the knowledge."* (SSA: Hoppers, 2009:114)

Research has shown that when attempting to improve mathematics achievement at the secondary level, whole-system interventions show successful improvements. For example, the ADEA report on post-primary education states: *"In addition to pre-service training, the institutions undertake interventions and research to improve various aspects of education at lower levels (e.g., the teaching of mathematics and sciences, building language competences, dissemination of innovations, in-service training, etc)."* (SSA: Hoppers, 2009:187). For improving this level of education in Africa, therefore, the author recommends the following:

- *Improve and diversify specialisations for teachers, with emphasis on science, ICT and mathematics*
- *Create appropriate networks of teacher resource centres and ICT-based training*
- *Design and implement programs for pedagogical and entrepreneurship training for Technical and Vocational Education and Training (TVET) trainers*
- *Promote teachers and trainers collaborating with industry leaders*
- *Foster pedagogical development programs for higher education staff*
- *Develop institutional management development programs*
- *Collaborate with basic education institutions in research and teacher development*

([SSA: Hoppers, 2009:242).

2. TPDL insights

This section introduces two key reviews on which the present review is built. These two reviews were purposefully chosen as they draw on international literature highlighting both what works in high-income countries as well as low and middle-income countries (LMICs). Synthesizing findings from various regions of the world is critical to determining contextualized best practices, or what works—and how—in different countries.

2.1. GITPD and DGT

The overall teacher professional development and learning (TPDL) insights presented in this report originate mainly from two reviews. The first review (GITPD) summarises the evidence-base in sub-Saharan Africa (with lessons for other low and middle-income countries (LMICs)):

GITPD
Haßler, B., Hennessy, S. & Hofmann, R. (2018). Sustaining and Scaling Pedagogic Innovation in Sub-Saharan Africa: Grounded Insights For Teacher Professional Development. Journal of Learning for Development, 5(1). Retrieved from http://jl4d.org/index.php/ejl4d/article/view/264

As the evidence-based for TPDL in SSA is not very well developed, the insights from GITPD are more tentative than the second review (DGT) which builds on the larger and more rigorous evidence-based literature available in higher income countries:

DGT
Cordingley, P., Higgins, S., Greany, T., Buckler, N., Coles-Jordan, D., Crisp, B., … Coe, R. (2015). *Developing Great Teaching: Lessons from the international*[2] *reviews into effective professional development*. Teacher Development Trust. Retrieved from https://tdtrust.org/about/dgt

Because of the different focus between these reviews (i.e., low-income vs. high-income countries), reliance on the findings — for the purpose of the present review — has to be considered carefully. As GITPD notes, much of the evidence in LMICs is small-scale. The discourse around rigorous and systematic teacher development research is more extensive in developed countries (↑Hill, et al., 2013, ↑King, 2014) and DGT outcomes are more secure; they pertain to higher income countries and may not always translate to low-income settings (Table 1).

In summary, all TPDL features discussed here align with:

A. the limited evidence from TPDL research in LMICs (i.e., GITPD and, e.g., Lange, 2014; Moon, 2007; Nag, et al., 2014:29; Orr, et al., 2013:75-76; Westbrook, et al., 2013:60-61);
B. the wider TPDL literature in developed countries (i.e., DGT and, e.g., Timperley, et al., 2007; Borko, et al., 2010, Table 2; EEF Toolkit, 2014), including Hattie's (2009)

[2] Note that the review was commissioned by a UK-based organisation; therefore, where DGT uses 'international' this is with reference to the UK, i.e., 'international to the UK'.

meta-analysis of over 800 factors influencing attainment, indicating overall large effect size (0.62) for professional development;

C. the insights from the school improvement tradition (Hopkins, Stringfield, Harris, Stoll & Mackay, 2014) as well as specific national insights (Ethiopia: Mitchell, 2015) and Leadership for Learning (Frost, 2014).

Given the existing evidence, it seems unlikely that somehow an entirely different set of insights would apply to TPDL in SSA; the above features constitute at the very least a sensible first approach to TPDL in SSA that needs to be taken very seriously in the absence of reliable evidence to the contrary.

2.2. The acronym 'TPDL'

DGT uses the abbreviation CPDL for 'continuous professional development and learning'. GITPD uses the abbreviation TPD for 'teacher professional development'. While these have different connotations in different contexts, for the benefit of the reader we use the amalgamated term TPDL ('teacher continuous professional development and learning').

TPDL
Teacher professional development and learning (both initial and continuous).

2.3. Effective TPDL

Our definition of 'effective TPDL' is teacher continuous professional development and learning (TPDL) that has an impact on student attainment. As demonstrated by DGT: *"Carefully designed/aligned teacher CPDL with a strong focus on pupil outcomes has a significant impact on student achievement."*

Indeed, the evidence seems to point out that among the interventions with an impact on student achievement, this may well be one of the strongest interventions possible (c.f., Hattie's meta-analysis; Hattie, 2009). However, such an impact will not be achieved if the TPDL is not well designed. Hence, both publications (DGT, GITPD) seek to draw out the characteristics of effective TPDL.

2.4. Validity of DGT for LMICs

As highlighted above, the evidence-based knowledge for TPDL in LMICs is less secure than for higher-income countries. When considering if the evidence from the higher-income contexts is relevant to the low-income contexts, we need to consider some of the key differences between high-income settings with low-income settings. Thus, the messages of the DGT (UK, high-income countries) need to be considered in relation to the setting in which it was generated and evaluated against the setting of GITPD (SSA, LMICs). Table 1 below outlines several of the differences that must be examined when considering the evidence-base of high-income countries in relation to low-income countries.

Table 1. Differences between high-income contexts and LMICs

	High-income countries	Low- and middle-income countries
School environments	The school environment is usually functional, offering a relatively safe environment for teachers and children. There are exceptions to this in certain areas marked by social inequalities.	School environments can be dysfunctional. In many settings, schools do not offer adequate sanitation for students. In some settings, female students are at the risk of violence, both in and outside of school.
Resource and infrastructure constraints (electricity, transport, writing materials, internet access)	Usually insignificant.	Usually severe in rural areas. Moderate even in urban areas.
Formal qualifications of teachers	While requirements for formal qualifications vary between school-types, higher-achieving schools will have well-qualified staff, that have undertaken reasonably effective initial or continuing programmes. However, due to staff shortages schools increasingly draw on lower-qualified staff.	In many contexts, initial teacher programmes are of poor quality, with a theoretical focus, that does not equip teachers to teach effectively. While the teacher-student ratio has improved, the qualified-teacher–student ratio remains low in many contexts.
Teacher motivation to teach	Teachers are often demotivated, and there are issues with teachers leaving the profession. However, while under contract, teachers will be active in schools.	Teachers are often demotivated, e.g., due to the prevalent infrastructure constraints, delayed payment, etc. In some countries, there are significant problems around teacher absenteeism.
Teacher appreciation of TPDL	Teachers recognise the importance of TPDL, for example as a prerequisite for career progression. It is fair to say that there is a 'culture of TPDL'. However, TPDL can be sidelined due to teacher workload.	There is often no culture of TPDL. An initial qualification (obtained at the start of the career) is seen as sufficient. As promotion is often not based on qualifications, teachers may not be motivated to undertake TPDL.

2.5. Security of insights

In this section, we review shared perspectives from DGT and GITPD for effective TPDL, arguing that in the light of these reports' scope and depth, the suggested principles constitute reasonably secure effective practices. For many of these principles the evidence-base is sufficiently strong and TPDL programmes would be best advised to stay within these principles. Any TPDL programme deviating from these principles would need to do so both (a) intentionally and (b) for well-argued reasons.

2.6. Mathematics education in SSA

In addition to DGT and GITPD, another significant reference to this study is the World Bank report *"Mathematics education in Sub-Saharan Africa: status, challenges, and opportunities"* containing data on Cameroon, Democratic Republic of the Congo, Ethiopia, Nigeria, Rwanda and Uganda entitled *"Mathematics education in Sub-Saharan Africa"* (MESSA):

MESSA
The World Bank Group. (2016). *Mathematics education in Sub-Saharan Africa: status, challenges, and opportunities (Vol. 2) : main report (English)* (No. ACS19117). Washington, DC. Retrieved from http://documents.worldbank.org/curated/en/538251476977591230/main-report

3. A systemic approach to TPD

It is becoming increasingly clear that narrowly focussed ‘solutions-driven’ approaches or ‘quick fixes’ do not result in improved learning outcomes for children. Instead, systemic approaches are starting to be favoured, which take a wider view, focussing in on specific obstacles as they arise (for further details, c.f. Haßler, 2019, Systems Leadership for Learning).

The following table illustrates the different systems aspects considered and the chapter where these are discussed.

Systemic approach to TPD		
Students (KG→primary→secondary)	Student-level factors. Factors that arise from students backgrounds, such as the languages spoken in their home.	Chapter 4
Classroom practices	Classroom-level factors to do with classroom practices, including teacher-student and student-student interactions in the classroom.	Chapter 5
Teachers	Factors to do purely with teachers (outside the classroom), such as TPDL, motivation, working conditions.	Chapter 6
School / community / clusters	School-level factors and factors that concern the community as well as clusters of schools (e.g. working together on TPDL).	Chapter 7
National level	National factors, including policy and policy implementation	Chapter 8

Clearly there are other factors too, such as the ecosystem of international donors.

4. Promote (and focus on) student learning

As stated above, ‘effective TPDL’ means TPDL that has a positive impact on student attainment. Both GITPD and DGT are clear that TPDL must promote — and focus on — student learning. TPDL that fails to focus on student learning will not have an impact on student learning. Thus, our first Principle is that effective TPDL must explicitly and directly promote and focus on student learning (GITPD, Characteristic #1). TPDL focused on student learning will inevitably focus on effective teaching practices. Learning comes first.

Principle 1: Promote and focus on student learning
TPDL must explicitly and directly promote and focus on student learning. TPDL must, therefore, focus on effective learning practices.

TPDL that does not focus on raising student attainment cannot positively impact student learning. Intentional action towards this objective is needed in order to achieve it.

GITPD stresses that effective classroom pedagogy, i.e. classroom pedagogy that improves learning outcomes and responds to local needs, is a necessary condition for sustaining and scaling TPD. The paper states that the strongest evidence of the most effective pedagogical practices in supporting pupil learning in LMICs comes from a number of in-depth and rigorous reviews, namely Westbrook and colleagues (2013) who found that (1) feedback, sustained attention and inclusion; (2) safe environments; and (3) drawing on backgrounds have an impact on pupils’ learning outcomes. Furthermore, the authors identified the following as practices that are characteristic of effective teachers:

- whole-class dialogue
- group work
- questioning
- pedagogical content knowledge
- code-switching
- lesson sequences

Westbrook and colleagues (2013:2) conclude:

> *“[These aspects] brought together as a package in an intervention or carefully constructed curriculum, supported by relevant professional development, they might make a considerable impact on student learning.”* (Westbrook, et al., 2013:2)

We also note that the EEF Toolkit also highlights the importance of feedback, metacognition, dialogic approaches and collaborative learning.

As DGT notes, there is a need to distinguish between (1) those types of professional learning aimed at operational and procedural knowledge, and (2) those types that are directly aimed at building on teachers' starting points to significantly enhance pupil learning. Examples for case (1) are workshops for instructing teachers on how to use fire extinguishers or how to comply with legislation or MIS systems. These may only require simple briefings and group discussion. The authors note, however, that professional learning which does not have a strong focus on aspirations for students and assessing the impact of changed teacher practices on pupil learning is not effective. This type of professional learning will, according to DGT, require *"sustained and dynamically interacting mix of activities"* (DGT:11).

We highlight that the goals illustrated in the operational and procedural knowledge type of TPDL (Case 1) lend themselves to a cascade model: the transmitted messages are simple and can be easily learnt through repetition. As indicated by DGT, the usual simplistic cascade models / multiplier models are ineffective (↑GITPD). Attempts to apply these models for any objective beyond the transmission of basic procedure oriented messages will not be successful. Regarding mathematics TPD, ↑MESSA stresses that *"interventions are most effective when they bring significant, positive changes to the daily experience of learners"* (p. 73).

4.1. Insights from mathematics TPDL projects

4.1.1. Students' attitudes towards mathematics

Student learning has different dimensions, including cognitive (knowledge and skills), affective (attitudes, feelings, values, motivations) and psychomotor skills (Bloom, et al., 1956). What does 'student learning' mean in the context of mathematics? A significant challenge with mathematics teaching is the way in which the subject is perceived by students. Their attitudes towards mathematics may be more negative than towards other subjects, constituting considerable barriers to learning. We can approach this issue by altering students' negative attitudes towards mathematics, and by fostering positive attitudes.

When focussing on altering negative attitudes, we must consider the different ways in which students who have a negative and/or distorted view of mathematics may reveal it, as each way will require a different approach. Zan's (2013, cited in MESSA:78) cites as examples of possible negative attitudes (1) a profound lack of self-belief and an expectation of failure, or (2) a fixed, instrumental view of mathematics. The remedial actions suggested by the author for each of these cases are as follows:

> *The first requires the teacher to instil confidence and reassure the student that success is possible. The second requires the teacher to change the student's perception of mathematics as a highly regulated, procedurally-led activity and to encourage a less rigid more creative approach"* (MESSA:78,citing Zan, 2013, European Mathematical Society).

Although there is a general agreement that positive attitudes of students towards the subject are important, Henderson and colleagues (2017) report that *"there is scant evidence on the most effective ways to foster them." (p. 9).* Nevertheless, creating a culture of positive attitudes towards learning in schools can be seen as a reasonable approach. The literature highlights that learning mathematics should be fun and relevant. This is an important contributor to creating positive attitudes towards mathematics. The MESSA report found evidence of *"the positive impact of competitive Olympiads on student attitudes towards mathematics at the highest levels. [... They] have proved effective in both identifying highly-talented students and promoting the status of mathematics as a subject." (p. 129).* These types of Olympiads, though more common in the region of Latin America and the Caribbean, have begun to make grounds in SSA.

Henderson and colleagues (2017) suggest teachers should build on pupils' informal knowledge, introducing the curriculum based on the understanding that children already have from their personal experiences. For example, teachers should highlight pupils' knowledge of sharing and proportionality that can be obtained in everyday life chores. By connecting learning to everyday life, teachers demonstrate to students the relevance of mathematics and its use in the real world. This may also alter students perceptions of self-efficacy, as struggling students might be encouraged by recognising mathematical skills they had not realised they had. Another alternative was implemented in a successful programme in New Zealand, where teachers showed their students how to try different approaches when faced with a problem and, most importantly, to view their mistakes as a resource for learning rather than evidence of their failure (New Zealand: ERO, 2018). By doing so, teachers may alter students' beliefs about their own ability to succeed.

Another good reason to pay attention to students' self-efficacy in mathematics — in other words, one's belief in his/her ability to succeed in specific situations or accomplish a task — is the impact that it has on pupils' achievement. The PISA 2012 report suggests that 'self-efficacy in mathematics' is strongly related to achievement. (MESSA) . As will be further discussed below, 'self-efficacy' and 'self-concept' — both measures of a student's belief in her/his abilities — are especially important when we consider gender disparities in mathematics achievement.

It must not be forgotten as well that attitudes towards mathematics can change from primary to secondary level. Henderson and colleagues (2017) indicate: *"there is a large dip in mathematical attainment and attitudes towards mathematics as children move from primary to secondary school" (p. 9).* Hence, the evidence suggests that the groundwork for successful secondary education lies at the primary level. This is especially true for mathematics, where basic skills serve as the groundwork for the later years.

4.1.2. The importance of basic mathematics skills

Mathematics as a subject is of the 'spiral' nature, meaning basic mathematical skills serve as the foundation and are essential for the development of more complex skills. Henderson and colleagues (2017) highlight the importance of mathematical fluency in basic operations by stressing that:

> "*It is likely that pupils who have problems retrieving addition, subtraction, multiplication, and division facts, including number bonds and multiples, will have difficulty understanding and using mathematical concepts they encounter later on in their studies.*" (Henderson, et al., 2017:18)

Student learning in the primary years of schooling, when these skills are expected to be developed, is thus a determining factor for success in the later years. The World Bank explains: *"teaching opportunities and learning potential at the junior secondary level depend strongly on the exit skills at the end of the primary level, particularly elementary skills like reading, writing, and basic mathematics"* (SSA: World Bank 2008:58).

4.1.3. Developing higher-order thinking skills and metacognition

A key aspect of learning mathematics is the acquisition of higher-order thinking skills. According to the definition in MESSA, these skills include:

- making sense of problems
- persevering in solving problems
- abstract reasoning
- constructing viable arguments

- critiquing the arguments of others
- mathematical modelling
- looking for and using mathematical patterns and structureTo support students' in the development of such skills, teachers can model procedures or critical thinking and reasoning strategies. Therefore, one way teachers can assist in the development of metacognition is by modelling their own thinking aloud for students (UK: Henderson, et al., 2017). Another example is to provide students with exercises that are already worked through, which allows students to analyse different possible procedures (UK: Henderson, et al., 2017). When students choose from different strategies and explain these strategies either to themselves or others, they develop metacognition. Metacognition is critical to developing higher-order thinking skills in mathematics. There is also evidence that 'mathematical inquiry communities' (MICs) can be helpful as children involved in these activities *"work in mixed-ability groups to discuss, negotiate and solve problems"* (New Zealand: ERO, 2018:45).

MESSA report also suggests that higher-order thinking skills need to be developed through carefully graded tasks that challenge students in the right way.

> *"Teachers [...] should select tasks with an appropriate degree of complexity allowing students to explore problems which can be approached from more than one direction. Such tasks promote the development of competing arguments and, hence, 'productive struggle in learning'. The NCTM argues that 'Effective teaching of mathematics consistently provides students, individually and collectively, with opportunities and supports to engage in productive struggle as they grapple with mathematical ideas and relationships' (NCTM, 2014, p.48)"* (MESSA:84)

5. What does effective teaching and learning look like?

The Education Endowment Foundation (EEF) toolkit[3] is a toolkit for teachers discussing effective classroom practices in relation to cost and evidence. It focuses on the United Kingdom and students in the age range of 5 to 16 years. The toolkit indicates that certain teaching practices are highly effective at a reasonable cost. These include feedback, reading comprehension strategies, metacognition, oral language interventions, collaborative learning and the use of ICT.

While the toolkit was developed in the UK context, the findings of the toolkit are broadly collaborated by our two key sources. It is, therefore, reasonable to assess the general applicability of the findings of this toolkit. In addition to this toolkit, the literature highlights a variety of strategies that are effective in mathematics teaching and learning. The following section discusses these key practices.

In light of this work, as well as mathematics specific insights (c.f. Following sections), we arrive at Principle 2 on effective teaching and learning practices.

Principle 2: Effective teaching and learning practices
Effective teaching practices to support student learning focus on feedback, metacognition and self-regulation, mastery learning, collaborative learning, oral language interventions and peer tutoring. Specifically to mathematics, these teaching and learning practices appear to be effective: (1) Connect math to the real world through experiential learning (2) Identify common mistakes and assess learning (3) Scaffold student learning through differentiation and the use of visuals (4) Leverage peer support (5) Promote culturally- and gender-relevant teaching

The five teaching and learning practices in this list are discussed in the following sections.

5.1. Connecting math to the real world through experiential learning

An important theme in the literature is ensuring that curriculum content is relevant to the lives of students. This is especially important in mathematics, where students may struggle to understand and value its use in real life situations. It is, therefore, recommended that teachers make explicit connections to real life examples as much as possible during classroom instruction (New Zealand: ERO, 2018:40). As previously stated, drawing on students 'informal knowledge,' or the ways in which they use mathematics daily, when sharing snacks with friends, for example, or helping their parents cook, is an effective way to make mathematics relevant for everyday life (UK: Henderson, et al., 2017:18). Likewise, teachers can incorporate mathematics and basic

[3] https://educationendowmentfoundation.org.uk/evidence-summaries/teaching-learning-toolkit

operations into world problems, stories, riddles, or culturally relevant fables (New Zealand: ERO, 2018:40). One way of doing this is by having students work on collaborative projects or tasks that have relevance to their lives, such as planning a school event using a given budget. Another way of providing hands-on and experiential learning opportunities is by organising a trip to the local market or corner store. In the later years, connections should be made to financial literacy where students are taught the importance of mathematics in agricultural production or other common practices relevant to the economy of their communities.

Finally, integrating mathematics across the curriculum helps both teachers and students value the use of mathematics in a wide range of fields and disciplines (New Zealand: ERO, 2018:41). Examining trends in natural disasters or weather patterns in science class, or analysing population data in social studies class are two examples that have appeared in the literature. Secondary-level TPDL interventions in both Senegal and Morocco have been identified as having a focus on developing teachers' skills in these areas of "applicable mathematics".

5.2. Identifying common mistakes and assessing learning

Teacher professional development courses should be designed with children's learning and wellbeing at the heart. The Education Review Office suggest that data from formal evaluations or informal feedback from students themselves should be collected and used to stimulate teachers' reflection and to inform future learning (New Zealand: ERO, 2018:32) . Based on Swan and William (2005 and 1995 cited in MESSA), MESSA argues that *"teaching becomes more effective when common mistakes and misconceptions are systematically exposed, challenged and discussed" (p. 102).*

MESSA presents two key elements of effective mathematics teaching: (1) the use of diagnostic testing to identify the needs of students early-on; and (2) the continuous administration of feedback to inform students of their progress. Teachers should be well informed of both general misconceptions in mathematics learning, as well as those mistakes that are specific to their students (UK: Henderson, et al., 2017:8). Assessment should be ongoing and used formatively so that teachers can adapt subsequent lessons and learning tasks to fit the needs of their students; this information should also be shared with students (MESSA). However, characteristics of the education systems common to LMICs — like multi-grade classrooms and large, overcrowded teaching conditions — represent obstacles to the implementation of the practices discussed above, particularly the use of individualised interventions, and the use of personal feedback. According to MESSA, in SSA:

> *"barriers to the adoption of formative assessment practices include: the tendency of teachers to dominate all aspects of teaching and assessment leaving little room for student-focused activities; poorly qualified teachers; large classes; poor facilities and shortages of teaching and learning materials"* (MESSA:111).

5.3. Scaffolding student learning by differentiating tasks and providing visual representations

MESSA suggests that teacher actions that promote adaptive teaching, where *"teaching methods are adapted to better match the needs and abilities of individual learners"* (MESSA:72), are effective for raising the achievement of students. Little (2009) calls this using 'accommodations':

> *"The use of accommodations does not alter the standard in mathematics or curriculum goal taught for mastery by the students. Instead, accommodations involve a wide range of techniques and support systems to assure that all students participate and demonstrate mastery of that standard in mathematics or curriculum goal"* (Little, 2009:23).

This applies to students with special needs, but also to the differences there are among students within the same class. Teachers should aim to adapt teaching and learning activities and assessments. For example, teachers may read a world problem to a student whose low literacy level serves as an obstacle to their mathematics achievement, or an assignment for a student who works slower may be to complete two problems rather than five, like the rest of his or her classmates.

Differentiating instruction can come in many forms. Another effective method that has been identified is by giving a multitude of exercises at varying levels for students to pick and choose those that they feel most comfortable completing: *"They had been given nine activities on 'must do' sheets and were required to complete four. The sheets were designed for four different ability levels"* (New Zealand: ERO, 2018:41).

The use of visual representations and manipulatives is another effective strategy to scaffold student learning. Drawing shapes when teaching fractions, using physical objects to discuss shapes and their properties, or providing students with number lines, graphs and charts are some examples (UK: Henderson, et al., 2017:8). It is imperative, however, that teachers and school leaders recognise that these visual representations and manipulatives are not a simple and direct antidote for learning. Rather, they are teaching and learning tools that must be utilised properly to help develop conceptual understandings; and they should be used as a temporary scaffold until students become confident in their ability to work through procedures independently (UK: Henderson, et al., 2017).

Likewise, prompts and visual guidance can be posted on classroom walls to scaffold student thinking and reflection. One example of this is the use of 'reminder cards' with sentence starters (e.g., *"I agree with your answer because…"* or *"My strategy is different from yours because…"*) that help students question their peers and promote collaborative thinking within the classroom (New Zealand: ERO, 2018).

Individual interventions may also be necessary, but they must be implemented with caution. Henderson and colleagues (UK: 2017:9)outline several characteristics of effective interventions:

- Interventions should start early, be evidence-based and be carefully planned;
- Support pupils to understand how interventions are connected to whole-class instruction;
- Interventions should motivate pupils — not bore them or cause them to be anxious;
- If interventions cause pupils to miss activities they enjoy or content they need to learn, teachers should ask if the interventions are really necessary.

Alternatively, in LMICs, where teacher free time is limited and extra staff may be unavailable to intervene, struggling students can be assisted within normal classroom settings and lessons. This may be done through peer tutoring or the use of heterogeneous grouping.

5.4. Using peer tutoring and/or heterogeneous grouping

Peer tutoring and support is another strategy that has been identified as effective for developing students' mathematics skills and knowledge. It is important, however, that those students chosen to help their peers are taught how to do so explicitly. For example, it should be made clear that students should not give the answers to their classmates, but rather explain or direct them towards the required mathematics procedures or concepts (New Zealand: ERO, 2018). When working with peer support, higher performing students can be paired with lower performing classmates to provide encouragement, support and guidance. For example, in one school reported in an Education Review Office study, teachers divided the class into pairs or small groups composed of students with different abilities, ensuring: *"that each target child always had the support of a more confident peer, plus access to more sophisticated strategies"* (New Zealand: ERO, 2018:61). The research found that simple measures, such as requiring children to share textbooks, worksheet or device were found to promote fruitful co-working practices and developed a shared sense of responsibility for the learning.

These types of interactions in the mathematics classroom have proven to have a range of positive effects. Pairing or grouping students — regardless of their ability levels — is an effective way of expanding students' learning opportunities. For example, MESSA report found that peer support allowed students to *"collaborate on the construction and evaluation of alternative approaches to solving a mathematical problem"* (p. 102). The Education Review Office study also remarks that *"students took risks and used their errors to improve their learning"* (New Zealand: ERO, 2018:58). Moreover, feedback from students tells us that they find it easier to understand their fellow classmates as they are likely to speak and express their thinking in similar ways (New Zealand: ERO, 2018:61).

A common concern when discussing working in the classroom with a purposely created heterogeneous group, is the worry that doing so can be a disadvantage for higher achieving student. The evidence indicates, however, that even the most able students progressed when working with peers. This is because when working in partnership, they are obliged to think more deeply about their problem-solving strategies and search for alternative ways to help their peers. (New Zealand: ERO, 2018:57).

5.5. Promoting culturally- and gender-relevant teaching

It is often the case in both LMICs and VHICs that ethnic minorities and girls are left at a disadvantage, especially in the maths classroom. Lack of fluency in the language of instruction or engaging in teaching and learning activities that are not relevant to a student's culture is a barrier to learning. The same goes for girls. If teaching does not tend to the specific needs and interests of female students, they will fall behind their male peers. Thus it is important that teachers make special accommodations for these students in order to create a more inclusive classroom environment.

5.5.1. The importance of language in mathematics learning

Many countries in Africa have more than one official language. In the case of Cameroon, for example, French and English are colonial languages that are still used as the language of instruction. Having parts of the population whose mother tongue is the local dialect, instead of the official language of instruction, is therefore not unusual. A consequence of this characteristic is that even when teachers speak several local languages, due to the great diversity of dialects present in the region, they might not be familiar with the language spoken by some of their students. As stressed by Howie (2003):

> *"The difficulty of not being able to communicate fluently in a common language is leading to increased frustration for the teacher, disorientation on the part of the child, a slow rate of learning, disciplinary problems and teacher centred instruction"* (Howie 2003:15).

Too often mathematics learning is impeded by language. Indeed, *"children who are taught and tested in languages that they do not fully understand are placed at a significant disadvantage"* (GMR, 2014, cited in MESSA*)*. While the language may be a challenge to teachers from all subjects, MESSA stresses that:

> *"the problem is exacerbated in mathematics where both teaching and learning depend on teachers and students understanding the special 'linguistic register' of mathematics"* (Pimm, 1987, cited in Setati, 2002; source: MESSA:99).

In order to address these challenges, teachers should provide language support to students. Again, this could be done by using visual scaffolding (UK: Henderson, et al., 2017) or 'reminder cards' to guide mathematical expression (New Zealand: ERO, 2018), as previously discussed. It could also mean preparing vocabulary lists for individual students or posting visuals with mathematical terminology on the wall for the whole class to see. Finally, using code-switching Westbrook and colleagues (2013) or training teachers in bilingual pedagogy (SSA: Bainton, et al., 2016:52) are effective strategies that equip teachers with the skills needed to bridge this cultural divide and create more inclusive classrooms.

5.5.2. Teaching gender-sensitive mathematics

MESSA has found that the challenge of achieving equal access to learning for girls is further complicated when working with mathematics and other STEM subjects because of subject-specific gender issues. The report states *"there are two main inter-related aspects: the underachievement of girls in mathematics especially at higher levels of the education system, and the under-representation of females in STEM study programmes at higher secondary and tertiary levels"* (MESSA:79). The author clarifies that the key factors contributing to the former are factors associated with: (1) access to a safe learning environment; (2) the perception of mathematics as a subject and as a career option; and, (3) teaching of mathematics in classrooms related factors. As an example of the latter, MESSA cites Boaler (cited in (Cech, 2012) study, where evidence indicating that *"boys typically outperform girls in schools where traditional methods based on memorisation of mathematical procedures and 'closed' assessment tasks"* (MESSA:82). When the tasks assigned were open, demanded deeper investigation, and if when exploring the problem students were allowed to collaborate, *"then both boys and girls improve but girls more so thereby closing the attainment gap"* (MESSA:82).

Some pedagogical practices that have been identified as helping raise female students achievement in mathematics include (MESSA:82):

- presenting mathematical problems in gender-appropriate contexts;
- setting mathematical problems that promote deeper understanding;
- using collaborative methods in the classroom;
- use of cognitive-activation strategies; and,

- using assessment methods which are not time-stressed.

However, Bethel also points out that the *"traditional emphasis on speed in the teaching and testing of mathematics is detrimental to students regardless of gender"* because they *"cause the early onset of mathematics anxiety... and are especially damaging for girls" (Boaler, 2014:1; cited in MESSA:83*). Teachers should thus be sensitised to these issues and ensure that they give all students, especially girls, the time and tools they need to succeed in the classroom; and instill in them excitement for learning mathematics.

6. Promote teacher learning

As well as promoting student learning, TPDL must promote teacher learning (GITPD, Characteristic #2). As we noted, this teacher learning has to focus on promoting student learning, rather than on other areas. In other words, teacher learning needs to be effective too, empowering teachers to support students to learn effectively within effective, inclusive classroom environments. This section considers what aspects of TPDL contribute to effective outcomes.

Principle 3: Teachers need to be recognised as professionals
Teachers must be recognised as professionals. TPDL must promote teacher learning in appropriate ways. If students are to become skilled (mathematical) problem-solvers and critical thinkers, teachers must be skilled (pedagogical) problem-solvers and critical thinkers too.

6.1. Recognising teachers as professionals

In order for TPDL to be effective, teachers must be recognised as professionals. Teachers often begin participation in TPDL with years of experience. It is important that this experience is not ignored nor undermined. Teachers' practical and professional knowledge should be recognised and valued as a means of not only motivating teachers to engage and participate in TPDL but to leverage their knowledge through collaborative dialogue and active learning. GITPD notes that:

> *"Rather than trying to 'plug gaps' in teacher knowledge, programmes ideally empower teachers to become reflective practitioners, able to identify gaps in their own knowledge and skill, and to acquire these as needed (Hardman, et al., 2011)"* (GITPD).

Teachers should be empowered as reflective professionals. This is done by addressing teachers needs, modelling interactive pedagogy, and providing opportunities for critical inquiry, active learning, and teacher collaboration. These elements are discussed in more detail below.

6.2. Addressing the needs of teachers

TPDL inevitably needs to be designed to address the actual needs of teachers. As in the case with student learning, this too should be backed up by data of teacher competencies or standards. Bainton and colleagues (SSA: 2016:52) recommend that schools and educational institutes *"fund diagnostic research to identify research gaps in teachers' knowledge."*

Moreover, in this identification of needs, school leaders can play an integral role. In the ERO's study of 40 primary schools across New Zealand, school leaders played a key role in identifying the strengths and needs of their teachers, making clear objectives based on the context of their schools and staff, and either providing internal TPDL or outsourcing other expert providers based on their needs and objectives (New Zealand: ERO, 2018:11).

In this case, leaders established specific targets, identifying the year levels, groups of students and operational domains they should focus on; this offers a clearer direction and reduced the tendency to focus on aspects of the curriculum where the children were already succeeding (New Zealand: ERO, 2018:21).

6.3. Modelling interactive pedagogy in TPDL sessions

Schweisfurth (LMICs: 2011:430) notes that *"interactive pedagogy is not only the message, but also the medium".* Teachers should be trained on interactive, learner-centred pedagogy by trainers and facilitators who model these instructional strategies in their TPDL sessions. The literature unanimously agrees that modelling effective teaching practices is an essential component of productive TPDL. For example, GITPD also flags the importance of modelling interactive pedagogy in teacher workshops (GITPD , Characteristic #2A). The ERO (New Zealand: 2018:19) expands upon this, recognising how external TPDL facilitators may model new teaching strategies and *support improved leadership practices.*

Modelling may happen at the classroom level as well. By inviting more confident colleagues into their classrooms, teachers can see their students being taught using new pedagogical strategies that may be unfamiliar to them. For example, the ERO (New Zealand: 2018:30) explains how successful programmes invited Mathematics Specialists Teachers (MSTs) to work with small groups of children within classrooms, so that teachers could observe their practice firsthand.

Still, workshops also need to model in other ways. Lesson planning is one example. DGT argues that TPDL leaders should *"model explicitly the quality and depth of planning for schemes of work that leaders are expecting teachers to create for their pupils and make these connections explicit."* In addition, the authors of DGT argue that contextualisation — for specific subjects, individual pupils, or groups of pupils (including advanced students or those with special needs) — must be addressed in TPDL modelling. They write: *"TPDL opportunities related to pedagogy is accompanied by time for teachers to contextualise this for specific subjects and groups of pupils"* (DGT).

6.4. Providing opportunities for active teacher learning

Teacher learning, like student learning, needs to be as active and learner-centred as possible. Workshops and training sessions should avoid models based purely on rote-learning methods of instruction, and should instead focus on modelling the type of learner-centred activities and exercises that teachers are expected to implement in their own classrooms. In other words, teachers need to be given meaningful opportunities to apply what they learn in TPDL. Examples of meaningful opportunities include whole class brainstorming, small group work or partner projects, as well as focused and critical collaborative dialogue. Overall, teacher trainers and facilitators should not simply lecture or *"give [teachers] materials without giving them opportunities to develop skills and inquire into their impact on pupil learning"* (DGT:8).

Inquiry especially encourages teachers to think critically about their approach to teaching and how to improve it. It allows teachers to examine their pedagogical strategies and the impact those strategies have on student learning. In order to guide this inquiry, therefore, it is important that teachers refer to hard evidence of student achievement (or lack thereof), as a way of examining where their practice may be improved. This auto-examination, a critical reflection on one's own practice, helps develop metacognitive skills. According to DGT, *"fostering a meta-cognitive approach among teachers was also consistently recognised as valuable for both bringing about change and sustaining learning."* (DGT). In fact, DGT points to the paramount importance of developing teachers' reflective practices, when they explicitly state that *"what* *does not work"* is *"professional learners [not being] given structured, frequent opportunities to engage with, understand and reflect on the implications of new approaches and practices"* (DGT:9).

6.5. Supporting participants in collaboration with peers

GITPD (Characteristic #2A) notes the importance of TPDL supporting collaboration with peers. Similarly, DGTnotes that *"the only common finding across all reviews was that peer support was a common feature in effective TPDL"* (DGT).

However, in general, it is unclear what exact form peer-support should take, and this is an area that requires further research:

> *"In the context of widespread but relatively unstructured collaboration, it would be helpful to tease out the distinctive characteristics of effective peer support and the dependencies between that and in-depth specialist support"* (DGT:13).

Existing TPDL models have different approaches to peer support, which we now consider.

6.5.1. Shared lesson planning

We note that the models described in GITPD do have fairly clearly structured collaboration (such as structured collaboration on lesson planning within teacher group meetings).

6.5.2. Structured peer observation and peer support (inside and outside the classroom)

Similarly, in the experience of the authors, making arrangements for structured peer observation (e.g., using specific forms) has been helpful; otherwise, the reflection at the end of lessons stays at the surface.

Within the peer support structure, less confident teachers could be partnered with more confident teachers as in the case of the school-based TPDL programmes in New Zealand (New Zealand: ERO, 2018:20).

Similarly, structures for mentorship could be put in place (SSA: Bainton, et al., 2016:52).

6.5.3. Collective Inquiry

Another shared activity is collective inquiry. It has been found, for example, that collective teaching inquiry can be a catalyst of positive change (New Zealand: ERO, 2018:12). Teachers looked closely at *"what they believed and whether their actions were consistent with their beliefs. If they noticed misalignments, they investigated how they could change their practice"* (New Zealand: ERO, 2018:63).

In the case of mathematics TPDL specifically, (New Zealand: ERO, 2018) identifies several approaches to collective teacher inquiry, including:

- Identifying students' strengths and weaknesses in mathematics and brainstorming possible reasons for these weaknesses;
- Having instructional leaders ask 'sensitive questions' that provoke teachers' deep reflection on their approach to mathematics teaching;

- Focusing on a school-wide TPDL structure that incorporates developing both teachers' mathematical content knowledge and pedagogical content knowledge.

6.6. Seeing, experiencing, reflecting

The cycle of seeing, experiencing and reflecting are powerful processes to enhance teachers' understanding of pedagogical practices and thus their effectiveness in the classroom. TPDL that incorporates video stimuli of live classroom practice, and provides the opportunities for teacher inquiry and their own practice can allow for this cyclical nature.

6.6.1. Video and microteaching

GITPD (Characteristic #2B) suggests that allowing for 'seeing' and experiencing teaching firsthand, through video clips of microteaching episodes or by observing live classroom practice, is the first step in improving teaching. Seeing is most helpful, however, when teachers focus on increasing their understanding of pedagogical practice. Carefully designed activities using video clips as a stimulus for discussion can be highly effective; rather than looking at live classroom practice, video clips allow teachers to practice their observation skills, with the benefit of being able to pause and rewind. This, of course, assumes that there are facilities for playing back video clips in the respective LMIC settings. Similarly, Bainton and colleagues (SSA: 2016:52)suggest the *"use [of] educational TV/radio/videos/ICTs to deliver training experiences and share expertise."*

6.6.2. Classroom-based activities and reflection

GITPD (Characteristic #2B) notes the importance of foregrounding concrete and detailed (planning for) classroom-based activities, combined with reflection on those activities. DGT also emphasises the importance of transitioning from TPDL activities to classroom-based activities when they write: *" All the studies noted that explicit discussions about how to translate CPD content to the classroom took place following initial input"* (DGT). In other words, TPDL should not only provide teachers with new skills and knowledge, but they should also provide opportunities to transform these new skills and knowledge into practical classroom-based activities. Once these concrete classroom-based activities are designed and critically considered, they must be trialled, and finally, this trialling should be followed by subsequent inquiry and reflection. This allows for a cyclical nature of professional development, and for an iterative process through which teachers can continue to fine-tune their practice and improve the effectiveness of their teaching for the specific context of their classroom and students.

6.7. Promoting mathematics teacher learning

The above principles also apply to teacher professional development for mathematics. However, there are several additional issues that must also be considered when developing mathematics teachers.

6.7.1. Reconceptualising mathematics

Mathematics as a subject, like many other content areas, is often conceptualised uniquely based on a teachers' cultural background. As the MESSA report argues, *contextualisation* is therefore of utmost importance, due to the fact that *"'culture' appears to be a key factor in determining the* *effectiveness of teaching/learning behaviours"* (MESSA:76.) In the context of LMICs, and in SSA in particular, teachers often perceive mathematics as a subject *"predominantly about rules and procedures rather than, for example, the exploration of problems and proofs"* (MESSA:101). This has implications for teaching:

> *"emphasis is placed on telling or showing learners what the rules are for solving a particular problem and, hence, what procedures are to be followed. The natural consequence is for the teacher to assume a dominant position and to hand the 'correct' procedure down to the learners"* (MESSA:102).

In other words, teachers' conceptions of effective teaching of mathematics as a subject that encompasses rules and procedures, causes them to employ what researchers refer to as an *"instrumentalist approach"* to instruction, ultimately leading to a more teacher-centred pedagogy. Overall, teachers' beliefs about effective teaching are generally a product of their culture and their own schooling experience. Because of this, mathematics TPDL must focus on transforming the culture of mathematics teaching as well as teachers' conceptualisations of what good mathematics teaching looks like.

Bainton and colleagues (2016) expand upon this and identify two additional key areas that mathematics TPDL must address in LMICs. Referring to these areas as *"critical areas that need specific support"* (SSA: Bainton, et al., 2016:52), the authors emphasise the need to train teachers in bilingual pedagogy, as well as develop their pedagogic content knowledge. Bilingual pedagogy is particularly important in SSA countries where colonial languages are often used as the language of instruction, leading teachers to feel less confident in their use of important terminology specific to mathematics teaching. Pedagogic content knowledge is critical to understanding common mistakes that students make and how teachers can address these mistakes in classroom instruction.

Once teachers understand mistakes that are common in mathematics teaching and learning, they may also begin to view their students' abilities in a new light. Teachers' expectations of students is a critical factor that determines student achievement. The ERO study in New Zealand found that schools where successful mathematics TPDL were implemented:

> *"...moved from an intervention model aimed at 'fixing the children' to a collaborative model where teaching professionals assumed collective responsibility for improving teaching, thereby reducing the need for future interventions. They refused to accept that so many children were simply not good at mathematics"* (New Zealand: ERO, 2018:11)

In other words, the mentality of teachers needs to transform so that they do not attribute students' underachievement to pupils themselves and see mathematics learning as an issue in itself, but rather as an opportunity to continuously develop their instructional skills in order to be more effective. At a school-level, this approach to mathematics TPDL allows teachers to collaboratively revolutionise teaching and learning, and to shift from a negative to a positive outlook on mathematics teaching and learning.

Finally, two other areas that need to be addressed are teachers' feeling of self-efficacy and the overall enjoyment that both teachers and students get out of the mathematics classroom. Even in developed contexts, it is critical that in mathematics TPDL school leaders work on *"building teachers' confidence with the new strategies before changing too much in the classrooms"* (New Zealand: ERO, 2018:30). Once teachers feel confident, and new pedagogical approaches are trialled, modified as needed, and found to be effective, teachers and students will be able to confidently enjoy mathematics classes. Overall, teachers need to be constantly encouraged to value and enjoy mathematics, just as students should. In fact, *"School leaders should ensure that all staff, including non-teaching staff, encourage enjoyment in mathematics for all children"* (UK: Henderson, et al., 2017:9). Ultimately, transforming mathematics teaching and learning needs to be a school-wide initiative that involves all educational stakeholders and transforms the school culture in general, and the culture of mathematics in particular.

6.7.2. How much mathematics does a mathematics teacher need to know? What kind of knowledge does a mathematics teacher need to know?

Mathematics has been previously described as having a *"spiral nature,"* meaning that fluency in basic numeracy skills and a students' capacity to demonstrate dominion over the four operations of adding, subtracting, multiplying, and dividing, impact their ability to master higher order thinking skills. But what does this mean for teacher knowledge? How much mathematics does a mathematics teacher need to know? What kind of knowledge does a mathematics teacher need to know? Ma (1999), as cited in the MESSA report, suggests that *"in order to teach elementary mathematics effectively, teachers need the confidence that comes through having a profound understanding of fundamental mathematics (PUFM)"* (MESSA:78 with reference to Ma, 1999). The author's suggestion implies that even those teachers working with students at the early levels of schooling should expand their knowledge to more advanced mathematical topics. This would, in turn, allow them to develop a more holistic perspective of mathematics as a subject, and more effectively prepare their students for the later years.

Moreover, teachers should be confident and possess high levels of *"subject knowledge (i.e., concepts and procedures) and pedagogical knowledge (how to teach mathematics)"* (MESSA:78). The report cites the work of Altinok (2013) who found five SSA countries, including Botswana, Kenya, Tanzania, Zanzibar, and South Africa, where teacher subject knowledge was positively associated with student achievement in mathematics classes(MESSA:96). The implications of these findings are straightforward: training teachers and improving their knowledge of mathematics as a subject leads to more effective teaching and learning.

Venkat and Spaull, however, expand upon this and suggest that *"the ability to teach students well [...] is not very dependent on subject knowledge, but perhaps more on the teacher's ability to convey that subject knowledge"* (Venkat & Spaull, 2015:23, cited in MESSA:96). This is where *pedagogical knowledge* comes into play. It is critical for teachers, both in SSA and elsewhere, to sufficiently understand *"how their students learn mathematics"* (MESSA:97). Developing teachers' pedagogical knowledge in general deals with ensuring that teachers have the instructional skills necessary to transform subject knowledge into concrete teaching and learning activities. Pedagogical content knowledge for mathematics, more specifically, would require teachers to understand how students learn mathematics, what the common errors they confront are, and how to address those issues in the classroom.

Finally, if students are expected to master higher order thinking skills, teachers must also be experts at modelling these competencies. In New Zealand, the ERO found several instructional strategies to be effective, including: *"talk moves to deliberately teach the children how to engage in problem-solving discussions with peers, [and] facilitating workshops with groups of children who needed to practise particular processes or skills."* (New Zealand: ERO, 2018:12). Conducting *"think alouds"* in which teachers say what they are thinking and how they approach a mathematical exercise out loud, for example, is one way of modelling higher-order skills. This sort of pedagogical instruction scaffolds student thinking and is an effective strategy that may accompany the sort of visual guidance and prompts previously discussed.

7. TPDL programming at school and cluster level

This section is concerned with the organisational principles of TPD, or as the ERO report describes it: *"a set of expectations and practices to be consistently applied school-wide"* (New Zealand: ERO, 2018:38). The first subsection presents somewhat securer insights that are supported by evidence from very high-income countries (VHICs). The second subsection presents insights primarily relevant to low-income contexts; necessarily, such insights were collected in low-income contexts, where the scarcity of research and corresponding evidence means that these insights may be somewhat less secure than the insights presented in the first section. The final two sections draw on insights from both high-income and low-income contexts and address the roles of various stakeholders, including school leaders and parents, families, and communities.

7.1. TPDL programming insights (VHICs)

Principle 4A: TPDL sequencing and length
TPDL needs to be carefully sequenced. They need to be long-term and need to be regular. In many contexts, this means that TPDL needs to be school-based. One-off training (e.g., 'residential workshops') does not work.

7.1.1. Scheduling continuous TPD

TPDL models that tend to focus on one-off 'top-down' teacher development 'interventions' are now recognised as being ineffective (Moon, et al., 2013; Bett, 2016; Wedell, 2009). For this reason, the importance of scheduling ongoing, long-term and continuous TPDL is critical for program effectiveness. Such structure safeguards TPDL from being sidelined:

> *"Concerns about giving time for CPD and TPDL are addressed by wrapping structured and explicit professional learning protocols and activities around work to meet other priorities and also used to build CPD capacity"* (DGT , UK contexts).
>
> *"The evidence also points to steps schools and teachers can take to ensure that, given the inevitable logistical constraints, there are structured arrangement in school to follow up learning from CPD programmes through sustained and iterative experimenting with and refining new approaches in the light of learning with and through pupils' responses"* (DGT , UK contexts).

Given that this is a concern in UK contexts, such structured arrangements are clearly crucial in LMICs. TPDL needs to have clearly scheduled meetings and be regularly timetabled within the school time table (e.g., for school-based teacher group meetings; GITPD).

7.1.2. Sequencing offers a logical thread

Within this structure, it is important that activities are sequenced. Within this, TPDL activities and processes need to be aligned.

> *"The review noted that, while it is necessary to have a variety of activities to reinforce messages and test things through different lenses, no single particular form of activity was shown to be universally effective. What mattered was a combination of a logical thread between the various components of TPDL, and the provision of opportunities for teacher learning which are consistent with the principles of student learning being promoted. No particular configurations were crucial to success, but aligning goals, activities, experiments in classrooms, engagement with evidence and underpinning rationale does matter alongside multiple perspectives and angles."* (DGT:8)

For example, within OER4Schools activities within sessions and between sessions are carefully sequenced to explore ideas coherently and systematically. Within professional development meetings and workshops, there should be clearly structured learning activities. In addition, subsequent to these meetings there should be *"follow-up activities"*, such as scheduled opportunities for teachers to trial new instructional practices and ideas in real classroom settings (GITPD). Overall, there needs to be rhythm to TPD: multiple instances of ongoing support/follow-up activities, in the form of biweekly or monthly schedules (DGT). TPDL should be a series of cyclical processes that allow teachers to learn new content through observation and collaborative dialogue, trial new pedagogical practices through lesson planning and implementation, and finally reflecting on this implementation in order to modify it and continue to iteratively adapt and improve one's instruction. The DGT refers describes the importance of creating a rhythm to TPDL in order to track teacher learning, writing:

> *"[...] developing creative ways of disaggregating INSET days to create a rhythm for TPDL, regular school meeting times such as departmental and phase meetings are used as opportunities for following up and tracking learning from CPD sessions"* (DGT).

7.1.3. TPDL needs to be long-term and needs to be regular

GITPD (Characteristic #4) notes that TPDL needs to be long-term. In many LMICs, it is hard to see how long-term TPDL could be organised unless this is scheduled as regular teacher group meetings. Therefore, TPDL leaders should try operating within a structured timetable. There are clear recommendations:

- TPDL should last at least one year if a tighter, more intensive schedule is possible (e.g., if there are strong motivations for undertaking TPDL, for example, a national government mandate with incentives, such as progression and salary);
- Otherwise, if there are no wider pressures to undertake TPDL, a programme less demanding for teachers should be implemented; such a TPDL programme would typically run over two years.

Similarly, DGT emphasises the importance of TPDL to be sustained typically for at least one year (in UK contexts).

7.2. Further TPDL programming insights (LMICs)

The insights in this section are less secure than the insights in the previous section. Nevertheless, there is a reasonable amount of research evidence that suggests that these insights are likely to be relevant in low-income contexts and thus deserve attention.

Principle 4B: TPDL adaptation for context

TPDL needs to be tailored and adapted to the local context. There are certain 'meso' factors normally considered important for such adaptation (country, region, school level, subject, national languages). However, there is some evidence that there are other 'micro' factors, pertaining to the individual circumstances of the school that may be equally significant.

Such factors include:

- The degree of expert input needed vs. self-sufficiency of the school;
- The cost of logistics (such as teachers travelling to a workshop venue or external experts or coaches travelling to schools);
- The benefits of working as a whole school (all teachers) vs. in segmented grade- or subject-specific groups of teachers.

It is well established that 'one size fits all' does not work. However, this typically means that we only differentiate 'curriculum' (e.g., TPDL for primary teachers, TPDL for secondary teachers, TPDL for secondary mathematics teachers, TPDL in French, etc). However, we rarely differentiate process, asking:"How much outside expert input does this school need? If there is limited outside expert input, which schools should receive it? Who are the most appropriate experts for which schools? What individual support does a particular teacher need? When we speak of differentiation for pupils, we, of course, mean differentiation by pupils, depending on their learning needs. By comparison, for teachers and schools, differentiation is not very well developed.

Summarising the key tenets of this section we suggest that TPDL:

- Comprises whole school professional development with a focus on active teacher learning and modelling interactive pedagogy (GITPD, Characteristic 2a)
- Supports peer-facilitated, school-based professional development (GITPD, Characteristic 3)
- Supports TPDL leaders in organisation and facilitation through induction and ongoing professional development (GITPD, Characteristic 5).

7.2.1. The role of the expert

If TPDL is to be led by expert pedagogues, then the role of these instructional leaders is of utmost importance. Teachers look to TPDL facilitators as experts in their field. However, these facilitators must not only be experts at teaching but also at modelling effective teaching and ensuring that teachers are able to transform these practices into meaningful professional learning opportunities. The MESSA report, for example, identifies two key needs of Teacher Training Institutes (TTIs) within the context of SSA:

- *"TTIs need to develop a cadre of tutors with the knowledge, skills and first-hand experience of classroom teaching necessary to deliver a reformed curriculum using active methods"* (MESSA:109)
- *"TTIs need to acquire the resources and personnel necessary to train their trainees in the effective use of the educational technologies both in the classroom and for personal development"* (MESSA:109)

This also means that placing inexperienced trainers in positions of power within TPDL frameworks can lead to grave consequences. Unfortunately, this is often the case in LMICs. Akyeampong and colleagues (2011) explain how *"tutors in TTIs tend to replicate their own ideas as to what primary school teaching looks like but that this, all too often, fails to mirror best practice"* (MESSA:107).

Other related findings regarding design features and contexts which need to be incorporated into TPDL for it to be successful are described below. A consistent message across all the reviews was that outside expertise was crucial in bringing about substantial improvements to pupil outcomes. In order for TPDL to result in an increase in student learning, it should:

- Make the public knowledge base, theory and evidence on pedagogy, subject knowledge, and strategies accessible to participants
- Help teachers (particularly those from schools where achievement is depressed over time) believe better outcomes are possible (according to the strongest study).
- Make links between professional learning and pupil learning explicit through discussion of pupil progression and analysis of assessment data.
- Take account of different teachers' starting points and (from the strongest review) the emotional content of the learning.
- Provide opportunities for specialists to support teachers by modelling, providing observation and feedback, and coaching.

However, It is unclear to what extent such contributions need to be made by an external specialist or to what extent this may arise from within the community of practice led by internal facilitators (who are sufficiently scaffolded through TPDL materials). This a factor of uncertainty even in high-income contexts, and DGT notes the following implications for further research:

> *"There would be real benefit in identifying specifically what it is that external specialists can contribute to effective CPD and TPDL and the implications of that for the growing numbers of internal TPDL facilitators"* (DGT:13).

Table 2. The need for experts vs. the need for peer-facilitators

A1. Expert-led, cluster-based / national workshops	vs.	A2. Peer-facilitated, school-based workshops

In conclusion, we argue that the role of an external expert is not fixed. The role of an external expert may be more or less important depending on the nature of the TPDL delivered and the specific local contexts of the teachers and the school. In particular, this may mean that within a national TPDL programme it would seem disadvantageous to prescribe the same amount of 'external expert time' for each and every school.

7.2.2. Location of TPDL

Identifying an ideal location for TPDL is an important logistical matter. There are several factors to consider, including convenience and commute, costs, as well as the resources and infrastructure available. This is especially important in LMICs, where teachers may have to travel long hours to get to schools, or where internet access, clean water and sanitary facilities may not be readily available. TPDL that is conducted at the school, without the teachers needing to travel to a workshop venue, and possibly without an external expert needing to travel to the school, has low logistical costs and would be an ideal option for holding workshops and other activities. Expert-led workshops are more expensive, and should only be used as a last resort, rather than as standard practice. When teachers are asked to travel long distances, one way to motivate attendance could be to offer to pay for transportation or to provide them with food and snacks throughout the day. Overall, the location must be convenient and welcoming enough for teachers to want to attend and participate.

7.2.3. TPDL for departments and whole-school TPDL

An important question is whether to undertake TPDL for groups within the school, such as lower vs. upper primary or one subject-group, compared to undertaking TPDL for all teachers at the school (i.e. whole-school TPD).

Table 3. Group-specific TPDL vs. whole-school TPDL

B1. Group-specific TPDL ('teacher deficit model')	vs.	B2. Whole-school TPDL (*"systemic deficit"*)

We note that whole-school TPDL does not mean that this TPDL is about general pedagogy. We know that general pedagogy does not work. So whole-school TPDL is still about subject-pedagogy. However, it does mean that the mathematics teachers interact with English teachers during TPDL activities. In this process, the mathematics teacher sees how the English teacher applies subject-pedagogy and vice versa. This has a number of advantages which are discussed below.

7.2.3.1. Learning from the most capable and inspiring teacher at the school

Suppose you have 40 teachers at a school. If you divide by subjects, you might only have 3-5 teachers per group. In LMICs, there may not be many inspiring teachers at any one school. What guarantees that the most capable and inspiring teacher at the school is in that group of 3-5 mathematics teachers? This is unlikely. Whole-school TPDL can build on the most capable and inspiring teacher at the school.

7.2.3.2. Mathematics across the curriculum

It is wrong to say that mathematics only happens in mathematics lessons. In New Zealand schools, success came when: *"Teachers revised their long-term plans and guidelines and/or extended children's opportunities to learn by integrating mathematics into other curriculum areas"* (New Zealand: ERO, 2018:12). The ERO reports that collaborative reflection and the sharing of best practices across areas of the curriculum is an effective approach to school-wide TPDL. All teachers can benefit from participating in these types of professional learning communities.

School-wide TPDL should also provide opportunities for teachers to collaborate across grade levels and subjects. We have previously discussed how both student achievement and attitudes tend to decline as they transition from the primary to secondary level (UK: Henderson, et al., 2017:9). Therefore, it is critical that across these levels teachers share effective practices and engage in productive professional dialogue. As Henderson and colleagues (2017) explain:

"primary and secondary schools should develop shared understandings of curriculum, teaching and learning" (UK: Henderson, et al., 2017:9).

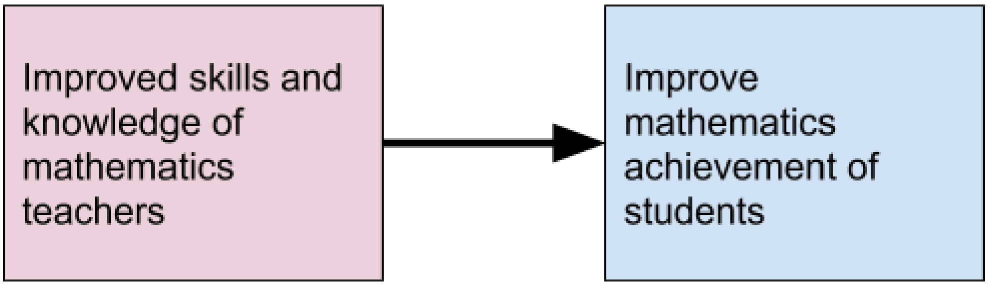
7.2.3.3. Certain teachers (e.g., in primary) may not have specialisations

At the primary level, certainly, in the lower years, it is often the case that a teacher teaches all subjects. In this case, it makes absolutely no sense to engage the teacher in TPDL solely for mathematics, without also addressing the other subject areas. This will only further the hard boundaries between subjects. Of course, the governmental perspective may be concerned about performance in one subject or another at the Primary School level. Likewise, certain funders may have a specific interest in promoting one subject or another. However, we do note that these are perspectives of agents external to the school. For teachers, the various subjects coexist within their pedagogical practice. Teachers should, therefore, be taught to apply their new subject-pedagogy understanding across the curriculum. As we remarked above, TPDL needs to sharply focus on the outcomes intended and integrating new professional learning across the curriculum.

7.2.4. Drivers of subject-specific TPDL

Often people and organisations that conduct or fund TPDL may have specific motivations, such as the lack of children's capability in a subject (e.g. in primary or secondary). A basic Theory of Change would suggest that improving mathematics teachers would also lead to improved student learning.

Table 4. A basic Theory of Change

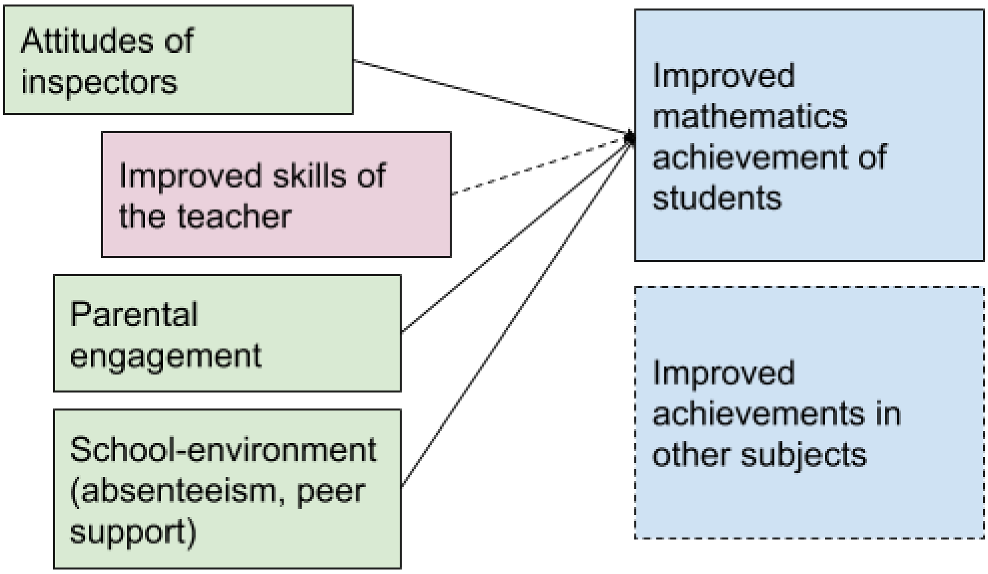


However, this basic Theory of Change rests on a number of assumptions, such as:

- The mathematics teacher has a reasonable classroom environment to translate their new skills into practice;
- The mathematics teacher is present for lessons;
- The mathematics teacher will remain at the school;
- The mathematics teacher is motivated to change their teaching practice;
- The mathematics teacher's new teaching practice is compatible with the enacted curriculum (as expected by inspectors);
- The headteacher and other teachers will be sympathetic towards the attempts of the mathematics teacher;
- Parents will be appreciative of the changes in teaching practice.

While such obstacles may be minor in VHICs, they are often prohibitive in LMICs (c.f. Table 1). In reality, the strong connection assumed in the Theory of Change above is not likely to exist.

Table 5. Some additional factors in a Theory of Change



In this way, 'sending a mathematics teacher to mathematics TPDL' assumes that the mathematics teacher is at 'fault' ('teacher deficit'). In LMICs it is much more likely that the core issues are to do with the school. In other words, such schools face a systems deficit, rather than a teacher deficit. In reality, it is often wider factors and/or the school-cultures that are to blame for poor school performance (c.f. Table 1 above). It is clear that in such circumstances the model outlined in Diagram 3 will do very little to change teaching practice.

7.2.4.1. Benefit of sharing subject pedagogy across subject boundaries

Clearly, there are differences in TPDL according to subjects. Even in the UK, this has implications for further research:

> *"The similarities and differences between effective [TPDL] in relation to mathematics, English and science as highlighted at headline level by this review are intriguing and potentially very important to practice, especially given the strong finding that pedagogic CPD alone is not effective. It is important to unpack these similarities and differences as revealed by the best studies encompassed by the most rigorous reviews"* (DGT:13).

However, we would argue that these only become important if basic subject-pedagogy is conquered. Until then, a struggling mathematics teacher benefits from seeing an inspiring English teacher from the same school. When mathematics teachers need specific inputs (e.g., on avoiding common misconceptions in specific mathematics topics) more specialised TPDL is mandated. However, in many settings teaching standards are not at that level, and the focus needs to be the school.

7.2.4.2. The importance of 'process'

Recent insights from TPDL research increasingly suggest that 'process' may well be as important as 'curriculum'.

- By 'curriculum' we mean the curriculum intended by the TPDL provider, written down in terms of competencies, learning outcomes, tasks and activities.
- By 'process' we mean how these activities are put into practice: Who conducts which activities together? Where and at what times? How regularly? What support is available?

For example, I might have a specific learning objective (e.g., 'understand positive discipline') accompanied by four one-hour activities on classroom management (i.e., a mini-curriculum to TPD). There are several options for 'process'. For example, two distinct models are:

Model 1. These four activities can be conducted in the course of one day, as part of a cluster meeting, or a cluster workshop led by an expert. Then teachers will be asked to implement the new strategies when they are back at school.

Model 2. These four activities can be part of a school-based programme, distributed over four weeks. In this case, there is no external expert present because they cannot travel to the school on a weekly basis. However, teachers have time to implement in their classrooms and collaboratively reflect between the activities.

The differences between these two approaches are clear: Model 1 has more expert engagement, but implementation at the school is left unstructured. In Model 2, there is far less time with the expert, but the implementation at school is more structured, therefore offering a clearer sequence.

As we noted above, certain micro-factors may mean that Model 1 or Model 2 is more appropriate given a certain set of circumstances. However, it is often simply taken for granted that the external expert input is absolutely critical and that, therefore, Model 1 is the only viable option. Consequently, the problem that follows is the supply of experts, which then leads to the adoption of a cascade model.

However, typically a cascade model means that, in practice, the expert may only be a 'relative' expert, who is only a few days of training ahead of other teachers. Therefore, it seems prudent to question whether such an expert is really expert enough to be helpful. Moreover, we may ask whether such a relative advantage could also be obtained through other means such as scaffolding peer facilitators through materials. If this is possible — as suggested by GITPD — then Model 2 may well be more favourable: it may offer quite comparable, potentially better, learning outcomes for teachers at a lower cost compared to Model 1. In other words, TPDL may well be a viable alternative as an alternative to the cascade model.

7.2.4.3. Evidence for and against simplistic cascade model

A basic premise of the cascade model may well be the assumption that good teaching is essentially due to teacher knowledge. If that were the case, transmission models would work. For example, for transmission of basic facts (e.g., operational and procedural knowledge, e.g., basic facts of or about HIV transmission) cascade models do work. However, teachers do not become effective through knowledge alone. Indeed, the research literature is quite clear that that knowledge is an important part, but by no means the only part.

Accepting the fact that teaching includes skills, let us like this to a master craftsperson or a master musician. Would it be possible to teach all teachers in a country to become master craftspersons through a cascade approach? Clearly, that is impossible. Yet, for teaching — an equally complex profession! — we assume that a simple cascade will suffice, or at least make a significant impact.

More than 10 years ago there was already awareness that cascade models can be very problematic. Ottevanger and colleagues (2007), for example, found that several countries *"acknowledge the vulnerability of the cascade model and the importance of the facilitators in the cascade model"* (Ottevanger, et al., 2007:85). Similarly, Bainton and colleagues (2016) more recently state that *"Generally, cascade models of delivering CPD involving the training of trainers are found to be less effective"* (SSA: Bainton, et al., 2016:46). A common finding among researchers is that a simple cascade model of teacher professional development is simply not effective.

However, there is some evidence of success with more complex models of cascade training. One promising example is the Science and Mathematics In-service Education and Training Services (SMASSE) Inset programme in Kenya. The SMASSE pilot programme was aimed at equipping secondary teachers with hands-on pedagogical tools to improve teaching and learning and implements a two-level cascade model of training. This two-level cascade model means that trainers are first equipped at the national-level and that subsequently, these trainers go on to facilitate training to teachers at smaller district levels. According to the project report, SMASSE was successful in (1) delivering training to teachers, (2) improving classroom practices, (3) positively changing the teacher and learner attitude towards mathematics and sciences, and (4) increasing science enrolments at the post-secondary level. More importantly, the two-level cascade model of training ensures *"the potential for duplication and enhancement" (Source: SMASSE, 2007, cited in SSA: Hoppers, 2009:115*). Still, however, this two-level cascade model does not come without its drawbacks. Michael and Orado (2009) highlight that not only does the two-level cascade model still face the possibility of dilution, but also the fact that two rounds of training exist means that it takes longer for impact and change to be seen in the classroom.

7.3. The role of head teachers and school leadership

Effective TPDL should be implemented at the school level and involve all school teachers and personnel involved. Thus, the role of school leaders is critical for ensuring successful TPDL design and implementation. When asking the question: *"How do school leaders effectively support professional development?"*, the *DGT* report concludes that "effective leaders did not leave the learning to their teachers—they became involved themselves" (p. 9). As discussed previously, school leaders should ensure that TPDL focuses on both student learning and the needs of their teachers. In addition, at the school level, leaders play a paramount role in ensuring TPDL is coherent across grade levels (New Zealand: ERO, 2018:14). Overall, headteachers should define clear objectives at the school level and hold all teachers to high standards. The Educational Review Office (2018) identifies several ways of doing this, such as the provision of *"topic overviews"* for specific mathematics subjects. Topic overviews are guides that:

- Align teacher training content and materials with school or national curriculum for each strand (e.g. statistics, geometry, algebra, etc.);
- Explicitly state the percentage of teaching time that teachers should allocate to each strand;
- Synthesises key learning strategies that students need to develop based on these various strands and national standards;
- Provide clear examples of what should be observed in the classroom (i.e. what should be seen and heard by students and teachers) to ensure effective teaching and learning processes(New Zealand: ERO, 2018:38).

In addition to the topic overviews, school leaders provided *"teaching guidelines they called 'essence statements'. For mathematics, these statements highlighted: (1) what should be present in the learning environment; (2) what teachers should know; (3) what the learning space programme* *must include; (4) Instructional strategies to be used; (5) what teachers should say and do; and (5) what effective pedagogy looks like"* (New Zealand: ERO, 2018:40).

Moreover, according to Green and Riddell (2012), cited in MESSA: *"the dominant factor in the acquisition of mathematical skills is the quality of schooling enjoyed by learners" (p.93).* School leaders must have the vision to look beyond the subject needs of students to ensure the overall school culture fosters a positive and safe learning environment.

Finally, it is important that school leaders themselves do not feel alone in their efforts to lead school-wide TPDL. Another effective strategy is to train leaders at different levels within the school system (i.e. not only the headteacher but also subject leaders or grade coordinators and other support staff) (SSA: Bainton, et al., 2016:53). Headteachers can also turn to other school leaders for support. TPDL does not need to stop at the school level, but rather teachers can draw on other school leaders' effective practices within their district or neighbouring communities. One example of this is found in New Zealand, where the deputy principal at a school *" visited other schools and examined research to learn more about programmes for gifted and talented students"* (New Zealand: ERO, 2018:29). Overall, school leadership is a crucial component of ensuring TPDL design and implementation is effective.

7.4. Parents, families and communities

"Transformation will not happen without the deep engagement of all stakeholders - particularly those whose voices are often less strongly heard — teachers and communities" (SSA: Bainton, et al., 2016:54). Involving parents, families and other community members contributes to improving overall teaching and learning processes. One way of doing this is to *"create new ways for community and schools to talk to each other"* (SSA: Bainton, et al., 2016:53). Parent involvement and home environment are inextricably linked to student learning (New Zealand: ERO, 2018:25). For mathematics learning, in particular, getting parents and family members to support students' development outside school hours is an effective strategy to both catch up struggling students as well as encourage advanced students to further their mathematical skills development. In New Zealand, for example, schools provided several opportunities to involve parents and community members, including:

- "Providing students with personalised activity books that include mathematical tasks appropriate to each learner's skill level. These activity books were to be done at home in the holidays to keep students practising during their time off" (New Zealand: ERO, 2018:25).
- "Sharing feedback with parents regarding children's needs and progress. Feedback should include both success stories and steps forward, or specific ways in which parents can support their children" (New Zealand: ERO, 2018:26).
- "Holding evening events for parents in which parents themselves were involved in learning tasks. Parents were taught ways in which they could support their students at home, how to look for mathematics in the everyday environment, or provided with visual and representational strategies. These events also allowed parents to recognize how the mathematics programmes were similar to or different from what they encountered when they were students" (New Zealand: ERO, 2018:34).

Ultimately, "by working with parents and situating mathematics learning in engaging and authentic contexts, teachers found they were able to accelerate the children's progress" (New Zealand: ERO, 2018:52). It is important to note, however, that parent involvement is often a challenge within LMICs, and thus these types of interventions must be adapted for the context of SSA.

Within SSA, according to the MESSA report, *"The achievement of a society's learners appears to be linked to the attitudes towards the learning of mathematics generally held by that society's non-specialists (rather than mathematics educators)"* (MESSA:77). Therefore, it is not only necessary to change the attitudes of students themselves, but also those members of the homes and communities that they come from. This is not only regarding teaching in general and mathematics in particular. It also includes issues of gender, for example. Within LMICs and especially SSA, it is imperative to sensitise communities to gender-based inequalities and their impact on education. MESSA cites the work of de San Román and de la Rica Goiricelaya (2012) who use data from PISA 2009 to determine that *"in societies where there is greater gender equality, girls perform better reducing their disadvantage in mathematics and simultaneously increasing their advantage reading literacy"* (MESSA:82). Holding meetings and events to inform the public of both the short and long-term impact of deeply seated cultural gender-biases is critical for making impactful change to teaching and learning, especially for girl students.

8. National level

Teaching and learning processes within classrooms and schools are inevitably impacted by policies and structures enforced at the national level. For this reason, (SSA: Bainton, et al., 2016:54) states:

> *"A focus on strengthening quality teaching needs to be mindful of the professional environment that enables this to happen: professional systems enable quality teaching, and achieving high impact demands careful consideration of the capacity of the system to support innovation. Strengthening high-level planning through Education Sector Plans was offered as a model that is able to identify gaps, and create greater coherence between actors and stakeholders."*

Education Sector Plans, in other words, involve conducting, *"detailed mapping to understand priorities, opportunities, and gaps"* (SSA: Bainton, et al., 2016:55). This allows for system-level improvement. However, within the context of SSA, *"Limited systematic mechanisms are in place to monitor the quality of classroom assessment practices"* (MESSA:111) This section aims to take a closer look at what some of these mechanisms may be in order to address issues at the national level, including teacher motivation, lack of resources, infrastructure and ICT, as well as the policy environment.

8.1. Teacher motivation

Principle 5: Teacher motivation
TPDL should appropriately motivate teachers (working in challenging settings) to engage, including attention to teacher career progression and salary structure (GITPD Characteristic #6).

In the region of SSA low levels of job satisfaction and motivation lead to *"far-reaching adverse impacts on the behaviour and overall performance"* of school teachers and thus learning outcomes (MESSA:93). In order to address these issues, (SSA: Bainton, et al., 2016:52)   several recommendations, including:

- Creating financial incentives for teachers
- Developing clear career pathways, including opportunities for advancement or accredited teacher training courses, or providing opportunities for teachers to take on leadership within their schools or elsewhere
- Recognising good teachers and schools with awards or prizes at various levels
- Running public campaigns to elevate the teaching profession

8.2. Resources: Teaching and Learning Materials

Principle 6: Teaching and Learning Materials
Teaching and Learning Materials (TLMs), including materials for teachers and materials for children should be Open Educational Resources (GITPD Characteristic #8). This increases sustainability, scalability and equity, as well as resilience against unforeseen changes.

Overall, there is a consensus among researchers that the provision of textbooks, teacher guides, and other teaching and learning materials is essential to improving teacher effectiveness. The Kenyan Primary Maths and Reading (PRIMR) initiative conducted by Piper and colleagues (2018) suggests that providing teachers without TLMs and only with professional development plus instructional support, results in very modest improvements insufficient to enhance student learning outcomes.

8.2.1. Textbooks and materials for students

The MESSA report cites the work of Fuller (1987) who claims that *"the availability of textbooks is a key determinant of learning outcomes especially in developing countries"* (MESSA:85). It is often the case that in LMICs where textbooks are available, the ratio of students to textbooks is large. Though this is at times seen as a challenge, as previously noted, the sharing of textbooks can be an effective way to encourage student collaboration. Authors have argued, for example, that *"textbook sharing does bring benefits — presumably through peer interaction and knowledge sharing"* (MESSA:87).

However, the provision of materials alone does not suffice. While the MESSA report emphasises the need for textbooks and other teaching and learning materials, they also recognise the need to utilise these tools effectively in teaching and learning processes. For mathematics teaching and learning, for example, the authors argue that the *"mere availability of mathematics textbooks"* will have little direct impact on learner achievement, *"as measured by test scores"* (MESSA:87). Rather, TPDL facilitators and school leaders need to ensure that: (1) the textbooks are aligned with the mathematics curriculum, and (2) teachers are able to use them effectively based on their students' needs. In other words:

> *"There is little point in investing in providing more textbooks unless those textbooks have been proven to be effective … if the mathematics curriculum is not well matched to the capacities of the majority of learners then simply providing a textbook will not bridge the gap."* (MESSA:87)

8.2.2. Materials for teachers, facilitators and education managers

In the context of LMICs, due to time constraints and challenging classroom conditions, the importance of providing teachers with materials is exacerbated:

> *"teachers are required to prepare their own classroom materials but that it is unrealistic to expect them to produce high-quality assessment instruments for formative purposes especially if they are inexperienced, have few resources to hand and are under pressure of time."* (MESSA:112)

GITPD recommends that materials for teachers, facilitators and education managers need to be made available and need to be:

> *"based on a coherent and comprehensive 'multi-level' set of resources, tailored to the national and/or local contexts, with activity-based workshop outlines, plus built-in support for facilitators"* ('whole programme scaffolding': GITPD , Characteristic #7).

Such materials need to be relevant to educators' day-to-day experiences and aspirations for pupils. There are a number of key 'building blocks' which underpin effective TPDL according to the reviews. In addition to subject and pedagogic knowledge, reviews emphasise the importance of clarity around learner progression, starting points and next steps (DGT). TPDL content should include a focus on formative assessment so that teachers can see the impact of their learning and work on their pupils. Once teachers collect evidence on their students' needs, they will be able to adapt their approach to teaching and tend to these students in order to ultimately improve learning.

Bainton and colleagues (2016) add *"supplementary reading materials"* to the list of important teaching tools (SSA: Bainton, et al., 2016:46). These sorts of reading materials provide teachers with self-directed opportunities to reflect on their own practice and how it relates to research, ultimately keeping them up to date with new findings in the field. Reading materials allow teachers to continue to engage in professional learning opportunities, on their own time and at their own pace, should they feel the motivation to do so.

Whilst there is controversy surrounding the approach of providing teachers with structured guides including scripted lesson plans, Piper and colleagues (2018) found that adding teacher guides to the package of teacher professional development, coaching, 1:1 student books had a "dramatic impact on student outcomes" (p. 333). These guides comprised of daily lesson plans with a partially scripted approach and the accompanying training focussed on how teachers could effectively utilise these within their teaching practice. Moreover, the cost-effectiveness analysis demonstrated that the added ingredient of teacher guides resulted in a remarkable increase in cost-effectiveness for improved student learning. The use of these structured guides may be particularly useful in LMIC contexts where teachers have less academic background and preparation than in Western contexts.

8.3. Resources: Information and Communication Technology

Principle 7: Information and Communication Technology
The use of technology in education ('educational technology', EdTech) has to be considered very carefully, as such investments have often not led to improvements in student learning outcomes. In the first instance, technology should be used equitably for essential communication and to support peer-facilitators in their facilitation of school-based TPDL (face-to-face, offline

peer learning in schools; GITPD Characteristic #9). It is of the utmost importance to learn from the past and heed established principles for digital development.[4]

In addition to paper materials, educational stakeholders are moving towards ICT and infrastructure. As stated by the World Bank, *"ICT proves to be a powerful tool when trying to shift teaching and learning to more active forms. It will alter teachers' roles to a facilitator in the teaching and learning process"* (World Bank 2008:66).

However, in LMICs, and especially SSA, a large gap presents itself. Schools and classrooms, especially in rural communities, are often disconnected from the internet and have little access to technology and other equipment. Where computers are found, several factors still hinder proper utilisation of equipment for teaching and learning purposes. For example, in the case of Cameroon:

> *"The use of information and communication technologies in teaching and learning in Cameroon secondary schools has been clearly low due to: low confidence and low competencies of the teachers, formal opposition by teachers to use pedagogical tools that they were not initially trained to utilised in a professional way"* (Cameroon: Haji, et al., 2017:152).

In other words, in order for teachers to effectively use ICT in developing contexts, they must be trained in computer literacy and the integration of such equipment into classroom instruction. Teachers need to feel comfortable and confident in their ICT skills.

Overall, research on the use of technology in classrooms has yielded mixed results. Authors of the MESSA report claim:

> *"there are numerous examples of evaluation reports making spectacular claims for the impact of adopting particular programmes and/or hardware in schools. However, rigorous re-evaluation of reported findings suggests that whilst positive benefits are consistently found, the effect sizes are generally moderate"* (MESSA:89).

In the case of mathematics, in particular, mobile phones continue to appear as a promising approach to effectively integrating ICT into teaching and learning. The ERO highlight three mobile phone applications that have proven to be effective: (1) *Show Me, an app with a voice-recording facility, to demonstrate mathematical thinking* (New Zealand: ERO, 2018:59) and (2) Explain Everything and (3) Shake, both of which allow students *"to identify the steps in a solution, manipulate digital materials and record thinking."* (New Zealand: ERO, 2018:62). The authors of the MESSA report agree and argue that *"providing information and teaching tools through mobile devices may offer the best opportunity for supporting teachers of mathematics — certainly in the short to medium-term"* (MESSA:101).

The authors also report, however, that one exception to this is the use of technology for Computer Assisted Instruction (CAI) and assessment. They cite the work of Yeh (2010) who found that CAI is especially effective at using 'rapid assessment' applications to conduct evaluations of student learning and provide on-the-spot feedback regarding students' progress and needs. Compared to other ICT interventions, CAI also yields greater effect sizes and is more cost-effective, thus suggesting that *"technology to support assessment for learning and to supplement usual teaching practice might bring significant returns"* (MESSA:90).

[4] https://digitalprinciples.org/

In fact, within the context of SSA, another promising practice is the South African subject-specific Assessment Resource Banks (ARB). Within the ARBs, *"Mathematics teachers can access sample assessment materials for a wide range of curriculum topics via the Thutong South African Education Portal"* (MESSA:112). A trend we begin to see in the literature, then, is the importance of using technology and ICT tools for assessment and evaluative purposes.

Still, technology as a teaching tool, if not utilised effectively, will not lead to learning gains: *"Technology is not a silver bullet — it has to be used judiciously and less costly resources may be just as effective"* (UK: Henderson, et al., 2017:9)

Technology for TPDL purposes, on the other hand, and especially for communication and collaboration purposes, has had positive effects. Distance learning opportunities, such as participating in Massive Open Online Courses (MOOCs) or utilising Open Educational Resources (OERs), for example, are all cost-effective and scalable approaches for teacher professional learning. Bainton and colleagues (2016) suggest that these online forms of TPDL may potentially, '*disrupt and transform the teaching profession and ensure their system wide adoption'* as they *"create platforms for teachers and educators to innovate and share good practice."* (SSA: Bainton, et al., 2016:55) An important next step would then be to: '*Engage innovators and entrepreneurs'* and *'Balance the tensions between aligning with government agendas and transformation through innovation"* (SSA: Bainton, et al., 2016:55). This draws attention back to the importance of ample consideration of the national policy environment.

8.4. The policy environment

8.4.1. Data and assessment

As part of their recent education strategy, the World Bank has developed the Systems Approach for Better Education Results (SABER). Within the SABER framework, data and assessment are identified as a key component to improving educational systems both at a national and global scale. According to the MESSA report, the SABER framework outlines *four major types of data and assessment: (1) classroom assessment; (2) examinations; (3) national large-scale assessments (NLSA); and, (4) international large-scale assessments (ILSA)."* (MESSA:87) The authors argue that at the macro level, *"information from international and national assessments can shape educational policies and, in some cases, spur the implementation of targeted reforms"* (MESSA:88).

8.4.2. Curricula

The national curriculum is a determining factor of teaching and learning processes as it outlines the skills and knowledge students must master in order to progress through the education system. In the case of mathematics the authors of the MESSA report claim that it is important *"to reduce curriculum overload and improve sequencing"* (MESSA:83). As previously described, mathematics is of the spiral nature, which means that sequencing is important to ensure that students develop fluency in basic foundational skills before advancing to higher-order thinking skills.

In addition, many LMICs have been reforming national curricula and shifting to a competency-based approach. In theory, a competency-based curriculum develops students' skills so as to promote both a hands-on approach to teaching and learning the application of said skills and content. It thus encourages teachers to use a more learner-centred pedagogy. However, due to cultural, political, and material differences, there is often a gap between policy and practice.

While the authors of the MESSA report emphasise the importance of curricula, they also recognise contradicting findings across the literature. For example, they cite the work of Slavin and colleagues (2009a), who in a literature review of studies analysing the impact of curricula, found that *'there was very little evidence that it mattered which curriculum was used. None of them showed any strong evidence of effectiveness in comparison to the others'"* (MESSA:83) They also reference Tarr and colleagues (2008) who claim, *"curriculum type was not a significant predictor of student achievement" (Tarr, et al., 2008, p247)."* (MESSA:83). Overall, while curriculum is a key component of the policy environment, there are inconsistent findings regarding the impact that curriculum has on student learning. This ultimately proves that it is but one of the many factors that needs to be considered in a systematic-approach to TPD.

8.4.3. Cohesion

Finally, in order for TPDL to be effective, there must be cohesion across all levels of the system, especially the policy environment. For example, if a new competency-based curriculum is to be effectively implemented, the teacher training institutions preparing pre-service teachers need to address these child-centred approaches in meaningful practice-based opportunities. Unfortunately, this is simply not the case in many LMICs:

> '*Research suggests that in many cases the institutions responsible for the pre-service training of teachers in SSA have not adjusted their own curricula and teaching practices to match the demands of the more modern curricula prescribed for schools"* (MESSA:83)

9. Conclusion

Worldwide, mathematics teachers face different barriers and challenges which can be detrimental to effective learning and student attainment. Negative student perceptions are often more persistent in mathematics than other subjects, and may stem from low confidence and self-efficacy or the view of mathematics as a rigid and highly regulated activity. Moreover, the 'spiral' nature of mathematics demands that students must possess foundation skills if they are to later acquire more complex higher-order thinking skills. Hence, the groundwork of basic numeracy at primary level is essential for later success at the secondary level.

Evidence suggests that these challenges can be mitigated by fostering effective learning and teaching methods within the classroom (Principle 2: Effective teaching and learning practices). Teachers should provide active and experiential learning opportunities for students to collaborate and learn together. Westbrook and colleagues (2013), identified whole-class dialogue, group work, questioning, pedagogical content knowledge, code-switching, and lesson sequences as practices characteristic of effective teachers which subsequently enhance student learning. Another recurrent pedagogical method is the connection of maths to real-life so content and skills are shown to be relevant to the lives of the students and valuable in daily situations. Integrating mathematics across the curriculum or encouraging families to promote mathematical thinking at home are two ways to make these real-life connections. Metacognition and higher-order thinking skills can be facilitated through tasks which encourage students to explore and analyse problems from multiple directions.

The need to scaffold student learning is essential in classrooms of students with a range of attainments and educational needs. Differentiated instruction and activities, alongside visual representation and guidance, are key strategies that can be utilised to adapt learning for mixed-ability classes. Furthermore, peer-tutoring in the form of group and pair work can provide pupil support and guidance, expand student learning opportunities and provide greater clarity than teacher explanation. Issues of culture and gender must also be addressed. Language development is essential to learning mathematics and should be accommodated using translation or language guides. The employment of gender-sensitive teaching and practices are also essential to encourage equal access of mathematics for girls. Students' individual cognitive and social needs must be seriously considered.

This type of differentiated instruction, however, can only be done through the proper use of evaluation. This means assessing students in a formative manner and constantly relaying feedback to them about their learning progress and needs. A cycle of feedback or assessment for learning serves to stimulate teacher reflection and follow student progress to inform future teaching and learning. Thus, effective TPDL must intentionally focus on student learning (Principle 1: Student learning). However, typical challenges faced in LMIC contexts - such as large class sizes, teacher-centred learning, and shortages of resources - are substantial barriers to the adoption of formative and summative assessment practices.

Effective TPDL must also promote teacher learning. Teachers undergoing TPDL, often with years of practical and professional knowledge, should be recognised as professionals and their prior experiences must be valued and recognised (Principle 3: Teachers as professionals). In order to empower teachers as reflective professionals, certain educational principles and approaches can be utilised. Firstly, like student learning, teacher learning workshops should be active and learner-centred. Inquiry-based activities can encourage teachers to think critically about their pedagogy and classroom practice, ultimately leading to a cycle of reflection and improvement. Moreover, these sessions should model the types of exercises that teachers are expected to implement in their own classrooms.

The needs of teachers should also be addressed in TPDL. Often headteachers can play a vital role by identifying areas of strengths and areas of improvements and forming clear objectives based on the school's specific context. Peer collaboration is a common feature of effective TPDL, yet it is currently unclear as to which structure or form is the most effective. A reflection cycle of seeing - experiencing - reflecting – improving can be emphasised and supported through video clips of teaching practice used as stimuli for discussion. In addition, TPDL should provide opportunities for teachers to put their new skills and knowledge into practice within the classroom and follow this with subsequent reflection to encourage teachers to fine-tune their teaching. Specifically within the subject area of mathematics, it is essential that TPDL reframes teacher mentality so that it is viewed as an opportunity to develop their instructive skill-sets, rather than as an issue itself. While mathematics subject knowledge is important, effective teaching is also dependent on the teacher's ability to translate that content to learning activities and therefore understand how their students learn mathematics.

Effective TPDL and training can be fostered through the application of programming and organisational principles. Importantly, TPDL should be a carefully sequenced, long-term and regular structure; one-off, 'top-down' interventions are now being recognised as unsuccessful (Principle 4A: TPDL sequencing and length). In most contexts, this requires a school-based model with scheduled teacher group meetings. Yet, as it is acknowledged that a 'one size fits all' system does not work, differentiated approaches for schools and teachers are required to adapt for local context and other 'micro' factors (Principle 4B: TPDL adaptation for context).

These structured TPDL sessions require facilitators and instructional leaders to ensure that teachers benefit from professional learning opportunities that enhance the learning of their students. However, research is unclear as to whether an external expert or supported peer-facilitator is more appropriate for this role. The location of the TPDL sessions is an important logistical matter, and depends on cost, commute length, resources and infrastructure. Ideally, the location should be convenient and welcoming so teachers are motivated to attend. Whole-school TPD, as opposed to selecting only a few teachers from a subject area or department, can be more beneficial to encourage cross-curricular links and enable teachers to learn from other capable and inspiring peers.

Evidence demonstrates that transformation is unlikely to happen without the engagement of stakeholders at different levels. School leaders, for example, are crucial in ensuring successful TPDL implementation and design and that needs of teachers and students are being met. Moreover, as the roles of parents, families and communities are closely tied to student attainment, actively involving family members to support students outside of school hours can be very beneficial.

Inevitability, teaching and learning processes are impacted by the policies and structures enforced at the national levels. Low levels of teacher motivation can be targeted and enhanced by financial incentives, clear pathways and accredited TPDL and recognition of good practice (Principle 5: Teacher motivation). Investing in resources for students – such as textbooks – is key, yet these tools must align with the curriculum and be used effectively by teachers for their students' needs. Furthermore, the TPDL materials for teachers, facilitators and education managers must be coherent and contextually relevant so that TPDL sessions are scaffolded and supported. The additional provision of teacher guides, with planned and partially-scripted lessons, have potential as a cost-effective approach for teachers with less academic and practical experience. The use of Open Educational Resources for these student and teaching materials can enhance sustainability, scalability and equity and enables easy adaptability of the resource (Principle 6: Teaching and learning materials). In the case of technology within education spheres in LMICs, mobile phones appear to yield promising results for teaching and learning. Using technology for TPDL purposes, such as with MOOCs or OERs, has been found to be a cost-effective and scalable method for distant learning. However, technology alone is not a solution: if the resource is not utilised effectively it will not lead to learning gains (Principle 7: Information and Communication Technology). The national curriculum is also a vital consideration in a systematic TPDL, as new curricula reforms may require a shift in the approach. A general cohesion across all levels of the system lends itself to the most effective TPDL.

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