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Promoting formative assessment practices in senior phase mathematics classrooms using meaning equivalence reusable learning objects

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South African mathematics teachers in the Senior Phase (Grades 8 and 9) were introduced to the pedagogical tool, meaning equivalence reusable learning objects (MERLO), as a formative assessment (FA) strategy to promote and support teachers' professional growth in using FA practices in the classroom. The cultural-historical activity theory (CHAT) and meta-didactical transposition (MDT) were used to frame the evolution process of teachers' praxeologies. In this study we used qualitative participatory action research that encompassed 3 phases: pre-MERLO phase, MERLO workshop and post-MERLO phase. The study was conducted in the northeast of Pretoria in the Tshwane district in the Gauteng province, South Africa. Twelve Senior Phase mathematics teachers were purposively sampled in 6 public schools before the workshop training. During the workshop training, only 5 teachers participated due to the COVID-19 outbreak. The data collection techniques included pre- and post-interviews, workshop training sessions, classroom observations, field notes, teachers' reflective journals, teachers' lesson plans, learners' workbooks and learners' worksheets, and data were analysed using thematic analysis. The findings reveal that the teachers acquired adequate knowledge and skills to effectively structure and integrate the lesson plan of teachers' didactical praxeologies as FA activities into their mathematics classrooms. The findings also reveal that the learners showed more interest and motivation, were actively involved, developed a deeper understanding of mathematics content, and showed increased autonomy in learning. Future research could involve implementing MERLO in all South African provinces and introducing MERLO to other emerging countries. However, the findings of this study are based on a limited sample of teachers and schools, and the recommendation is that, for future studies, more teachers should be involved in the MERLO professional development.

Keywords: formative assessment; mathematics classroom; MERLO pattern; teachers' workshop training

Introduction

One of the key issues in education in the 21st century is how teaching and learning (T&L) activities and assessment can best be organised to reach the intended outcomes effectively. Biggs and Tang (2011) describe this as the alignment of T&L activities and assessment with the intended learning outcomes of a course of study. Teachers must realise that the assessment method should align with a lesson's intended outcomes. South Africa has implemented a variety of educational changes since the country's return to democracy in 1994, such as Outcomes-Based Education (OBE), the National Curriculum Statements (NCS), and the Curriculum and Assessment Policy Statements (CAPS) (Bantwini, 2010; Chisholm, 2005; Jansen, 1998). Educational changes were implemented in reaction to the apartheid government's creation of disparities and imbalances in the education system. OBE shifted the teaching approaches from teacher-centred to learner-centred in compliance with educational reforms (Calvin, 2019; Maharajh, Nkosi & Mkhize, 2016).

In this study, we explored Senior Phase (Grades 8 and 9) South African mathematics teachers' understanding of formative assessment (FA) and FA strategies used in their T&L. We also investigated the challenges that affect teachers' effective use of FA practices. We introduced the teachers to a new FA technique called meaning equivalence reusable learning objectives (MERLO) with the hope of improving South African learners' mathematics achievement. This study was undertaken in the northeast of Pretoria in the Tshwane district of the Gauteng province of South Africa. Although only Gauteng was considered in this study, future plans involve introducing the rest of South Africa, and other countries with emerging economies, to the MERLO approach, as some first-world countries have already been introduced to it.

Background of the Study

Assessment is inseparable from the T&L process; Wiliam (2013) emphasises that assessment is the bridge between teaching and learning. Classroom assessment practices have globally been a continuous focus (Muskin, 2017; United Nations Educational, Scientific and Cultural Organization [UNESCO], 2015). However, studies have revealed that more attention is placed on summative assessment (SA) (assessment of learning) as opposed to FA (assessment for learning) (Birenbaum, DeLuca, Earl, Heritage, Klenowski, Looney, Smith, Timperley, Volante & Wyatt-Smith, 2015).

In the South African education system, assessment consists of school-based assessments (SBAs) and examinations (Departments of Basic Education and Higher Education and Training, 2011). SBA involves gathering valid and reliable information about the learners' performance on an ongoing basis against clearly defined criteria using various methods, tools, techniques, and contexts (Poliah, 2019). SBA includes all forms of evaluation performed by teachers at classroom level, but it is a subjective form of assessment; as Reyneke, Meyer

and Nel (2010) highlighted, if each teacher developed their own assessment, it could lead to an imbalance in the scoring of assessments. SBA is directed by the curriculum documents and the national assessment policy; thus, a methodical significance is placed thereon, creating an assessment imperative (Poliah, 2019). However, SBA is one of the curricula reforms that has not been implemented effectively in South Africa (Poliah, 2019).

South African learners constantly perform far below the excepted standard in mathematics compared to their international peers. This low performance is confirmed through comparative studies, such as the Trends in Mathematics and Science Study (TIMSS) (Reddy, Winnaar, Juan, Arends, Harvey, Hannan, Namome Sekhejane & Zulu, 2020). South Africa participated in TIMSS on Grade 5 and Grade 9 levels in 2019. The focus of this study was on Grade 9 level and, at this level, South Africa scored among the lowest of the 39 countries with an average scale score of 389 in mathematics – well below the international benchmark of 500 points (Reddy et al., 2020). TIMSS sets the low benchmark at 400 points, with a score above 400 indicating that learners acquired basic mathematical knowledge. Reddy et al. (2020) report that only 41% of South African mathematics learners demonstrated that they had acquired basic mathematical knowledge (scores above 400), meaning that 59% of South African learners have not acquired basic knowledge. Although FA holds many advantages for T&L, Kanjee and Mthembu (2015) found that while South African teachers, in general, had a low level of understanding of summative assessment (SA), their understanding of formative assessment (FA) was even lower. Likewise, Dliwayo (2019) points out that SA is emphasised more than FA in South African schools and maintains that the pressure on teachers to meet the subject content requirements (i.e., complete the syllabus) means that teachers have little time for engaging in FA tasks.

Studies have shown that teachers are struggling to apply FA assessment strategies in the classroom because they demonstrate a lack of knowledge and understanding thereof, have a lack of support and training on how to develop quality FA materials and have a lack of support and training on how to incorporate it effectively in T&L (Chong, 2009; Govender, 2019; Kanjee & Croft, 2012; Poliah, 2019; Vandeyar & Killen, 2007). If teachers are properly trained, they will design and develop sound assessments (Govender, 2019). There is a need for professional teacher training in FA for South African teachers, and we intend to address this issue. The training suggested here is in MERLO development. Arzarello, Kenett, Robutti, Shafrir, Prodromou and Carante (2015) state that MERLO is an effective FA technique since it allows continual feedback regarding learners' deep conceptual thinking and understanding of mathematical concepts. Robutti (2015) states that MERLO could be applied as FA to get input regarding learners' conceptual understanding of mathematical concepts, and it could help teachers develop new knowledge and skills relevant to designing their lessons. Therefore, introducing South African teachers to MERLO as a form of FA could improve learners' conceptual understanding of mathematics, potentially improving achievement in mathematics and, ultimately, improving the quality of mathematics education in South Africa. With the study we aimed to investigate the impact of MERLO when used for T&L in Senior Phase South African mathematics classrooms. The objectives were to explore teachers' notions regarding FA and what FA strategies they use, how FA strategies, specifically MERLO, are used to promote FA practices in Senior Phase classrooms, and the challenges that teachers face when implementing MERLO as FA strategies.

Research Questions

This study was part of a larger participatory action research project that sought to answer the following major question: What is the impact of MERLO when used in Senior Phase South African mathematics classrooms for T&L? The secondary research questions supporting the primary research question were:

SRQ1: What are Senior Phase mathematics teachers' notions regarding FA?

SRQ2: What FA strategies do Senior Phase mathematics teachers use?

SRQ3: How can MERLO (as an FA strategy) be used to promote FA practices in Senior Phase classrooms?

SRQ4: What challenges do Senior Phase teachers face when implementing MERLO as FA strategy in mathematics classrooms?

Literature Review

The most relevant literature related to this study was reviewed with the central interest in the notion of FA; empirical evidence of strategies that support FA; the pedagogical tool, MERLO, and the possible challenges of integrating FA in the classroom.

Notions of formative assessment

Assessment in the classroom is a process that involves both teachers and learners in the ongoing monitoring of learners' needs (Wiliam, 2011). Black and Wiliam (2018) advocate that assessment is a process for building a basis of evidence and reasoning related to the courses of action that could improve learners' learning. Based on Flórez and Sammons (2013:3), assessment serves as a formative purpose which means "it thus differs from assessment designed primarily to serve the purposes

of accountability, or of ranking, or of certifying competence." Different types of assessment exist and the difference between the two main forms of assessment (SA and FA) was first pointed out by Michael Scriven in 1967. Wilson (2018) asserts that SA is used to give a summary of what learners understand and not to assist in providing effective feedback in which learners are involved. In contrast, FA is used to inform and engage learners in their own assessment, identify the areas for learners' strengths and weaknesses, and to provide effective feedback (Clark, 2015; Nusche, Earl, Maxwell & Shewbridge, 2011; Perry, 2013). FA seeks to find learners' prior knowledge, their current level of understanding, and how they can achieve their major goals in learning (DeLuca & Volante, 2016; Wiliam & Thompson, 2017). Thus, FA and SA might collaborate to impact learning since "what is needed is the integration of SA and FA activities into a functional system so that they work in concert to support and evaluate learning" (Clark, 2015:93). Bennett (2014) indicates that schools need formative elicited evidence for decision-making about learner learning in the classroom culture and summative evidence to evaluate learner achievement.

Scholars recommend that more attention is focused on FA rather than SA since the aforementioned is connected with enhancing learner learning (Birenbaum et al., 2015; Spector, Ifenthaler, Sampson, Yang, Mukama, Warusavitarana, Dona, Eichhorn, Fluck, Huang, Bridges, Lu, Ren, Gui, Deneen, Diego & Gibson, 2016). This strategy implies that the inappropriate use of FA should be addressed by considering its correct link to learner achievement in learning because when teachers are motivated and supported to use FA effectively, the betterment of learner achievement will follow (Andersson & Palm, 2017; Cornelius, 2014; Yan & Cheng, 2015).

Empirical evidence of strategies that support formative assessment

The review of international studies indicates the essential components of FA strategies to practice FA in the classroom to enhance learning and support raising learners' achievement in learning (Black & Wiliam, 1998a, 1998b; Heritage, 2010; Iowa Department of Education, n.d.; Wiliam, 2013). Various researchers argue that FA strategies might, when applied effectively, create a dynamic process that would shift the focus in the classroom from teaching to learning (Black & Wiliam, 2009; Moss & Brookhart, 2019; Organisation for Economic Co-operation and Development [OECD], 2005; Ross & Donahoe, 2020). Effective FA strategies require of teachers to create a learning environment that integrates FA and actively involves individual learners and their peers in learning (Ross & Donahoe, 2020). Moss and Brookhart (2019) state that FA's key strategies should address the role of the individual component to reinforce learners' learning (Moss & Brookhart, 2019).

Several studies confirm the impacts of effective questioning that support FA in T&L (Barrett, Magas, Dedhia, Gruppen & Sandhu, 2016; Bartlett, 2015; Fusco, 2012; Mason, 2010; Wiliam, 2011). These impacts advocate that effective questioning should start by planning and relating the lesson with learning objectives. The objectives could be shared by asking open-ended questions. The questions should be followed by permitting a waiting period, paying attention to learners' responses, carefully assessing and following up on those responses with alternative questions (i.e., paraphrasing learners' questions), and re-planning with regards to learners' responses. Scholars further suggest that teachers ask good questions to obtain sufficient information about what learners are learning. Teacher questioning techniques are only effective if they interest, motivate and involve learners in learning. In addition, questions should assess prior knowledge and understanding in learning and activate present knowledge to create new understanding. The questions should concentrate on learners' thinking on the key concepts, increase and deepen their thinking and promote thinking about how they learn, and identify the gaps and misconceptions in learning (Barrett et al., 2016; Bartlett, 2015; Fusco, 2012; Mason, 2010; Wiliam, 2011).

According to scholars, the effective use of FA in the classroom is based on the active involvement of learners in the assessment of individuals and peers in their classroom, which can be achieved by activating learners to be independent in their learning and to become learning resources for one another (Black & Wiliam, 2009; Forrester & Wong, 2008; Sherrington, 2019; Wiliam, 2011). In various studies, scholars recommended peer- and self-assessment (PASA) as an FA strategy that teachers could employ to engage and promote learners in their own and peers' learning. Sherrington (2019) advocate that PASA involves the quality and occurrence of active learner interactions to assist learners in assessing their own learning in terms of making progress. Studies indicate the importance of engaging learners in their own learning through PASA. Various scholars define peer-assessment as a set of activities involving learners taking responsibility and providing feedback for judging the work of others against established success criteria. In contrast, self-assessment is defined as a process where learners are required to assess and reflect on their own work regarding how well they performed against a pre-determined standard that engages learners daily to achieve and establish their measurable goals in learning (Bartlett, 2015; Bourke & Mentis, 2013; Ndoye, 2017; Reinholz, 2015). In other words, PASA encourages learners to develop interest and engage in instruction by reflecting on

their own misconceptions, inspiring learners to increase their learning.

Researchers have shown that feedback has a significant effect on learners' learning when a teacher provides feedback while assessing learners' work before the learner can move on to subsequent activities (Boud & Soler, 2016; Brookhart, 2017; Irons, 2008; Sadler, 2010). Formative feedback creates a significant regular dialogue that occurs between teacher, learners and peers to support and guide learning, assist learners in identifying their strengths and weaknesses for improvement, and in identifying the subsequent steps to follow in their learning (Carless, 2016; Carless & Boud, 2018; Gravett & Winstone, 2019). Bartlett (2015) and Carless (2016) assert that feedback is an ongoing process, not a product acted upon during any given period in the lesson; it should provide an opportunity for learners to improve their knowledge. Although formative feedback can promote learning, not all the replies to learners help them improve their learning (Carless, 2016; Hattie & Timperley, 2007). Globally reviewed studies indicate that teachers experience some challenges in providing feedback to their learners because they are unaware of whether feedback given to learners is formative (Lee, 2008, 2011). Lee (2008, 2011) further indicates that teachers provide feedback on learners' misconceptions and neglect reinforcement for learners that need to be improved. Therefore, Senior Phase mathematics teachers need to be aware of and support the evolution of MERLO participation. Effective formative feedback helps learners close the gap and enhance their conceptual understanding of learning mathematics (Brookhart, 2017; Lee, 2011).

The pedagogical tool, MERLO

Since the 1990s, MERLO has been a pedagogy and teaching technique developed, validated, and experimented with in different countries and in different content areas and disciplines (Etkind & Shafrir, 2013; Etkind, Shafrir, Kenett & Roytman, 2016). MERLO has evolved and has been validated, tested and implemented in different countries (Australia, Canada, Israel, Italy, Russia and the Netherlands) and in various content areas and disciplines (Arzarello et al., 2015; Etkind & Shafrir, 2013; Etkind et al., 2016; Persoons & Di Bucchianico, 2020; Prodromou, 2015; Robutti, Carante, Prodromou & Kenett, 2020) but not yet in African countries. MERLO is a "multi-dimensional database that allows the sorting and mapping of relevant concepts in a given knowledge domain through multi-semiotic representations in multiple sign systems including exemplary target statements of particular conceptual settings, and relevant statements of shared meaning" (Etkind et al., 2016:106). MERLO is a pedagogical tool appropriate for different versions of core content based on sharing the meaning across different forms of representation (Robutti, Arzarello, Carante, Kenett, Prodromou & Shafrir, 2016). MERLO is a powerful tool for problem-solving mathematical concepts known as duplication obstacles, extensive in all mathematics classrooms. Details of how MERLO works are provided in Appendix A.

Possible challenges of integrating formative assessment in the classroom

Studies suggest that teachers who integrate effective FA activities to involve learners in the classroom facilitate learner development of a comprehensive understanding of learning (Earl & Timperley, 2014; Florian & Beaton, 2018). To foster the relationship between effective FA integration by teachers and learner development, it is important to acknowledge that integrating and sustaining the concept of FA in the classroom presents challenges (Hattie & Timperley, 2007; Laveault & Allal, 2016; Shute, 2008). However, despite these potential challenges to FA being incorporated effectively reported worldwide, these concerns also relate to the South African context.

Research indicates that understanding and integrating FA in the classroom improve learners' learning, but many teachers misunderstand its use (Harris, Brown & Harnett 2014; Izci, 2016). However, scholars state that teachers do not fully understand and know how to integrate FA to address learners' needs and provide quality feedback in the classroom (Harris et al., 2014; Izci, 2016; Smith, 2011). Other studies indicate that teachers' misinterpretation of FA and inconsistent use of FA in the classroom could result from inadequate support and time constraints (Black & Wiliam, 2006; Izci, 2016; Mkwananzi, 2014; Smith, 2011). Govender (2019) and the OECD (2013) also indicate that teachers misunderstand what FA involves because they are not fully trained. Musa and Islam (2020) state that teachers who had participated in training complained that the training was not based on practising FA but focused only on core content. Scholars concur that teachers' misunderstanding of what constitutes formative assessment brings about difficulties for teachers to plan to fully integrate effective FA in the classroom to improve the T&L process (DeLuca, Luu, Sun & Klinger, 2012; Heritage, 2010; Moss & Brookhart, 2019). Studies reveal that teachers' workload and overcrowded classrooms hinder their planning for interactive FA (Dessie, 2015; Lumadi, 2013). In overcrowded classrooms teachers spend extra time marking, which reduces the lesson time specified in the CAPS document (Department of Basic Education [DBE], Republic of South Africa [RSA], 2012). Teachers believe that various contextual factors mean that FA cannot be integrated effectively in the classroom (Carless, 2016; DeLuca et al., 2012; Izci, 2016). Izci (2016) mentions that lesson duration, and many

administrative duties impeded the integration of FA in the classroom. Izci (2016) further indicates that it is difficult for teachers to assess learners' learning in an overcrowded classroom because class control and effective feedback are problematic. Studies point out that the barriers that impede FA in day-to-day activities include the extensive curriculum provided and the time required for assessment, which adds to the difficulty of meeting learners' needs in the classroom (Looney, 2011; OECD, 2009).

Conceptual Framework

The conceptual model is shown in Appendix B and is briefly discussed here. The model is presented as an interdependent relationship and is adapted from the theories of T&L that support FA in terms of constructivism and a socio-cultural perspective (Vygotsky, 1978), an activity system perspective (Engeström, 2001, 2015), the concept of self-regulated learning (Zimmerman, 2002), and the meta-didactical transposition (MDT) framework (Arzarello, Robutti, Sabena, Cusi, Garuti, Malara & Martignone, 2014; Robutti, 2018). The conceptual framework related to the FA of mathematical concepts starts with the interdependent relationship between the mediators of the object-oriented activity being the tools, subject, object and outcome, and the theories that underpin FA in T&L, which are discussed in detail in Appendix B.

Research Methodology and Design

In this study we followed a qualitative research approach, and the research strategy adopted was participatory action research (PAR), which is a subset of action research (MacDonald, 2012). Gillis and Jackson (2002:264, as cited by Phillips, Trevan & Kraeger, 2020:227) define PAR as the "systematic collection and analysis of data for the purpose of taking action and making change by generating practical knowledge." The PAR process builds opportunities to empower and support participants to re-think and change their practices in the education sector (Kemmis, McTaggart & Nixon, 2014; Riel, 2019).

Participants and Data Collection

The sampling technique that underpins this study is non-probability purposive sampling. Non-probability sampling was used to gather information that is important for the phenomena. Purposive sampling, which is a non-probability sampling technique, was used to select the schools and the participants for this study. We selected participants non-randomly in terms of certain common qualities, knowledge, and experience that the participants might possess (Etikan, Musa & Alkassim, 2016). Twelve Senior Phase mathematics teachers were purposively selected from six public schools. Although 12 participants were initially part of this study, eight dropped out after Phase 1[i] due to the Coronavirus disease (COVID-19)[ii] leaving only four teachers in Phases 2 and 3. However, in SCH1,[iii] a teacher heard of this study and volunteered to participate in Phases 2 and 3, even though he didn't participate in Phase 1. Due to the small sample size, we accepted the voluntary participation. This arrangement resulted in a total of five teachers in Phases 2 and 3.

Data were collected using semi-structured interviews (pre- and post-interviews), workshop training session, classroom observation, document analysis (teachers' lesson plans and learners' workbooks) and field notes. The cultural-historical activity theory (CHAT) model for training in the pedagogical tool, MERLO, and its outcomes, is illustrated in Table 1. For detailed information, see Figure B1 in Appendix B and Phase 2 under Findings and Discussion.

Table 1 CHAT model for training in the pedagogical tool, MERLO, and its outcomes

Activity and actions	Teachers' MERLO training participation	Source of data
Subject	Before the MERLO participation, 12 Senior Phase mathematics teachers (Grades 8 and 9) were involved. During MERLO participation and post-MERLO participation, only five Senior Phase mathematics teachers were involved due to the COVID-19 pandemic.	Observing the initial teachers' praxeologies processes of evolution over time by sharing their experiences (theoretical reflection). The source of the data is: • Pre- and post-interviews • Classroom observation Lesson plans • Learners' workbooks • Learners' worksheets • Teachers' reflective journals
Object	Developing an exemplary lesson plan and developed hand-out for MERLO workshop training.	
Tools	Textbook (Mathematics CAPS), lesson plan, and teachers' experience, teaching materials (MERLO items design, white boards markers, learners' worksheet; copies of MERLO template).	
Community	School community (learners).	
Rules	School culture, norms, T&L environment.	
Division of labour	Community of researchers and teachers working together on a task that would be designed for classroom activities. Community of teachers involved in the task enact the lesson to their learners in the mathematics classroom.	
Outcome	Teachers understand the guiding principle to plan and design a lesson plan and the effectiveness of designing MERLO questions for learners.	

The evolution of teachers' praxeologies was based on observing the initial teachers' praxeologies processes of progress over time by sharing their experiences (theoretical reflection) (cf. Table 1). The findings were analysed using thematic analysis by organising, arranging and structuring data into meaningful patterns, themes and categories. Data recorded on audio were carefully transcribed and coded.

Methods to Ensure Trustworthiness

Trustworthiness was ensured through data and methodological triangulation (Creswell & Creswell, 2018). Data triangulation was achieved since data were collected from several sources to corroborate the facts. Methodological triangulation was achieved by gathering data through multiple methods. Trustworthiness was ensured by member checking, i.e., participants were given copies of their transcripts to confirm the accuracy thereof.

Findings and Discussion

Phase 1: Findings from Pre-MERLO Participation

We conducted pre-interviews and classroom observations and examined teachers' lesson plans and learners' workbooks before the participants attended the MERLO workshop, and the following themes emerged.

Theme 1: Notions of FA and strategies used to support FA

Sub-theme 1.1: Teachers' understanding of FA

All the teachers knew that FA was used to verify what learners had learned and whether they had understood the lessons. Only two teachers (SCH2-MT2[iv] and SCH6-MT2) mentioned its use to verify whether the learning intentions (LIs) had been reached. Two of the teachers focussed on the "formal" aspect of FA. SCH5-MT2 mentioned the following: "*FA, I can say that it is a formal assessment. This means to be recorded to tell the learners in terms of progression*." SCH2-MT1 stated: "*FA is like formal assessment. That will be a test, exams and assignments*." From the pre-interviews and classroom observation it was clear that the teachers did not understand what determined fully formative assessment. This might be due to the confusion about exactly what FA entails, and the literature also points out that such confusion results in inconsistent FA practices in the classroom (Arrafii & Sumarni, 2018; Black & Wiliam, 2006; Clark, 2012).

Sub-theme 1.2: Strategic formative questioning

The pre-interviews revealed that all the teachers used questioning as a form of the teacher-centred approach in the classroom. Classroom observation and notes jotted down in our field notes show that all the teachers only employed short-response questions, which did not stimulate in-depth thinking (Heritage & Heritage, 2013). Teachers need to ask learners well-thought-out, open-ended, high-level questions that promote learners' higher-order thinking and reflection (Staunton & Dann, 2016). Teachers asking low-level formative questioning would not provide the necessary feedback to motivate the learners. The classroom observations confirmed the ineffectiveness of the teachers' questioning as many of the learners did not actively participate during the question and answer (Q&A) sessions. The classroom observations also confirmed that none of the teachers allowed the learners enough time to express themselves when answering questions. The teachers only called on learners who raised their hands. The classroom observations contradicted what the teachers claimed doing in class during the pre-interviews, for example:

> *It helps the learners to be more interactive in the lesson. Otherwise, you are going to rush through everything without making sure if they understand. So, every 3 to 4 minutes, you must pause, ask a random question to random learners, make examples, and try to assess whether they understand what you say.* (SCH2-MT2)

To effectively sustain formative assessment in T&L, the recommendations of Barrett et al. (2016), Bartlett (2015), and Wiliam (2011) emphasize commencing with open-ended questions, incorporating a deliberate pause, attentively considering learners' responses, and meticulously evaluating those responses.

Sub-theme 1.3: Substantive formative feedback

By examining learners' workbooks and through responses in the pre-interviews, we found that 10 teachers gave written corrections and marking as feedback, and two used peer-marking as feedback. SCH4-FT1 stated as follows: "*We are doing peer-marking; they mark each other's books, and then I just go to the board to explain*." SCH1-MT2 said, "*We do peer-marking*" and complained that written comment to address misconceptions in learners' workbooks was difficult and stressful, so he relied on doing corrections because it was quicker and easier:

> *The comment I make; I don't make them in a book because that is tasking. I won't finish. Remember, our class is hectic. You know the ratio; one class is 50 something and educator. So, marking comments is difficult. The comment that I made is only when we do corrections is easier and quicker on the board.* (SCH1-MT2)

We found that some teachers gave evaluative and interpretive feedback (such as "well done", grades or rankings). SCH3-MT2 stated: "*When I give them their marks, I call the names of the top 10 and congratulate them, and I call the names of the bottom 10 and tell them to pull up their socks*." SCH6-MT2 mentioned: "*I make comments on their note by saying, 'well done'. I also make a list of their names and marks and put this on the wall*." Overall, the findings show that most teachers lacked the skills

to effectively use formative feedback to meet learners' learning needs; only two teachers gave constructive formative feedback. Not providing constructive formative feedback is a major concern, as Goldin, Narciss, Foltz and Bauer (2017) note that "formative feedback is well known as a key factor in influencing learning" (p. 385).

Sub-theme 1.4: Peer- and self-assessment

When asked what strategies teachers used to support FA in their lessons, participants listed group activities, weekly tests, monthly tests and verbal questions. Very few specific FA strategies were mentioned. Only two teachers mentioned the "*peer-to-peer*" strategy. SCH2-MT1 stated, "*Peer-to-peer sometimes, it does help the learners to understand it faster than if it from the teacher*." The same teacher stated: "*There is also the peer role, I mean the pair-leader-role where you ask the learners who understand in the class to come and present so that they are not only listening to me*." Another teacher mentioned that the pair-leader-role enable their learners to work as a team:

> *I usually do pair-leader-role. I just randomly selected one learner from the class. But normally, it's the learner I know who is not struggling, so they can show other learners because some learn better if they are hearing it from their peers*. (SCH4-FT1)

The classroom observations confirmed that teachers were reluctant to actively involve learners in assessing their work and working in cooperative groups. Teachers preferred face-to-face[v] teaching without involving learners in any PASA. Findings from the pre-interviews show that most teachers were unwilling to include learners in individual and group activities due to overcrowded classrooms and time constraints. SCH3-FT1 stated: "*My classes are always crowded, so sometimes it impossible to create a group discussion and let them sit in groups that will be chaotic and the environment will not allow us*." Another teacher mentioned that

> [i]*t depends on how difficult the concept is that we are doing. We spend more time on algebra than we would on financial mathematics. It depends if you have the time, then you can do that, but if you don't, you try and push through.* (SCH2-MT1).

According to the literature, peer-to-peer learning promotes logical thinking skills, allows learners to understand interactive social learning, and enhances learners' engagement in class activities (Ndoye, 2017; Wiliam, 2013).

Theme 2: Application of FA strategies

Sub-theme 2.1: Frequency of FA integration in the classroom

In the pre-interviews, five of the teachers mentioned that FA strategies were integrated daily. Six teachers mentioned that learners were assessed either twice a week, weekly, after every two lessons or every 2 weeks, and one of the teachers mentioned that FA happened depending on the availability of time: "*It depends; I will say it is not every time*" (SCH2-MT1). From classroom observations and examining the teachers' lesson plans, it was evident that not all teachers used FA strategies daily. The fact that this was not done daily was not of great concern, as Steyn and Adendorff (2020) state that the frequency of questioning should not be the only focus, but rather the participation by and developing of understanding by the learner.

Sub-theme 2.2: The integration of FA in the classroom

In the pre-interviews, some teachers explained that the integration of FA strategies in the classroom was not planned because different methods were used depending on how the class progressed. SCH4-FT1 mentioned that, "*Sometimes questions come when I am busy teaching, then I will try by all means using different methods so that I can at least try to help those who do not understand*.". SCH2-MT2 stated: "*You will find out you are supposed to give these learners you assess three levels, but because of time and overloaded work, then you assess only one* [level]." As studies suggest, integrating different FA strategies into everyday practice allows teachers to have comprehensive details about their learners' levels of understanding to determine where changes should be made (Curry, Mwavita, Holter & Harris, 2016; Moss & Brookhart, 2012, 2019). However, teachers seemed to inconsistently implement FA strategies to assess learners' understanding due to their own misunderstanding of effectively using FA strategies and several contextual factors that hindered their effective use of FA.

Theme 3: Challenges in implementing FA strategies

Sub-theme 3.1: Lack of resources, space and time

Five teachers mentioned that a shortage of resources and instructional materials were significant factors hindering the effective implementation of FA. SCH3-FT1 mentioned: "*There are not enough resources to make stimulations because they need to see the gradient you need to show them. So, the resource plays a huge role*." SCH5-MT1 mentioned:, "*We are experiencing a very shortage of textbooks. The number of textbooks is very few; they have to share all of them*." SCH1-MT2 mentioned: "*Projectors we have got very few*." SCH4-FT1 said: "*When dealing with the geometry part, it needs an instrument, and these learners do not have it as they are from a poor community*." These shortages were also visible during the classroom observations and are of great concern as Visser, Juan and Feza (2015), who analysed South African TIMSS 2011 data, found that the school's capacity to provide instruction (where this was affected by a shortage or inadequacy of resources) was one of the strongest predictors of mathematical performance.

Another major challenge is overcrowded classrooms. Eight teachers mentioned that the number of learners was more than 50, and there was

no space to move around to check what learners were doing. This challenge was also evident from the classroom observations. SCH1-MT2 mentioned: "*There is no space, one thing for sure if you can go now 50 something in a class*." SCH1-MT2 mentioned: "*My biggest challenge is overcrowding. I have close to 60 learners in one class; I cannot move around*." SCH4-MT2 said: "*Our classes are overcrowded, so it is not easy to move around and see the learner who is not doing anything*." These overcrowded classrooms pose a problem. Oguejiofor and Obiakor (2020) state that "class size has significant impact on the appropriateness of teachers' instructional strategies" (p. 1). Three teachers mentioned limited time for implementing FA strategies. SCH4-MT2 said: "*The contact time is never enough. There is a lot of work, especially mathematics*." SCH1-MT1 mentioned that "[t]*ime is a very serious problem. Sometimes we won't just reach everything if there is limited time. The learners there are those who are very slow to do the work.*" SCH4-FT1 mentioned: "*I do not have enough time because I am also teaching other grades. And their work is very demanding. Even my timetable is so congested that during that free period, I need to rest.*" These challenges are serious as Willis (2011:399) points out that "it is impossible to achieve visible learning results if time and other resources are limited and that the consequence is teaching to the test."

Sub-theme 3.2: Training and support required

The teachers indicated that support should be provided regarding the strategies that will work best in mathematics teaching. The teachers suggested that organising training and workshops for them on applying different teaching strategies could effectively enhance their T&L process. SCH6-MT2 mentioned: "*I think the government and district are not organising enough workshops and training. Training and workshops should be provided for teachers on how we can apply different teaching methods in the teaching of mathematics.*" SCH1-MT2 stated: "*I would like us to be developed again because I can't say 'yes, I know', because things change. Many other strategies other people are developing; I need that*." The gap in teachers' understanding and practice of FA techniques needs to be addressed through ongoing professional teachers' training programmes. According to scholars, practical, professional training programmes would assist teachers in developing proficiency, knowledge, skills and other features in the T&L process (Jovanova-Mitkovska, 2010). This notion of developing teachers' professional knowledge and skills should be a long-term, proactive and constant process in the social phenomenon (Birenbaum, Kimron & Shilton, 2011; Jovanova-Mitkovska, 2010).

Phase 2: MERLO Workshop (Teachers' Meta-didactical Praxeologies)

According to Chevallard (2019), the evolution of teachers' praxeologies, such as teachers' meta-didactical and didactical praxeologies, comprises the practical components (i.e., task and technique) as the "praxis" (p. 87) and the theoretical components (i.e., technology and technique) as the "logo" (p. 92). The findings of the MERLO workshop training reveal that participants were strictly involved in working together during the process of designing the task (MERLO pattern) in the workshop training sessions using the technique and the corresponding theoretical reflections. "The teachers are introduced to a task; The teachers use a technique to solve it; The teachers know why they choose such a solution; The teachers justify technique and technology with a theory" (Robutti et al., 2020:63). We provided a hand-out and guidelines for organising the activities on the pedagogical tool, MERLO, to participants.

The first component, known as the "task", is considered important, as it focuses on what the teachers need to know and understand in terms of a detailed account of what MERLO entails (cf. Sub-theme 1.1), how MERLO items are designed, known as the "techniques" cf. Figure 1) and the process of using the key FA strategies in terms of incorporating effective questioning, PASA and feedback across the lesson plans for their learners (Kanjee, 2017; Wiliam, 2013) (cf. Theme 1, Theme 2 and Theme 3). Figure 1 is an example of how teachers designed MERLO items on the topic "decimal fraction", and the item's design process being in sequential order of TS-Q2-Q3-Q4 (cf. Appendix A).

Instructions	TS	Q2a
1) Mark all statements that share the same mathematical meaning – at least 2 out of 5 statements 2) Write down the thoughts that guided your decisions.	A [ ] Decimal fraction 0.833	B [ ] Shape 

Q2b	Q3	Q4
C [ ] Fraction	D [ ] Decimal fraction	E [ ] Percentage
$\frac{5}{6}$	0.462	67%

Figure 1 A MERLO item question about decimal fractions

Teachers indicated that the TS was created in a decimal fraction format as 0.833, which was the main question, followed by Q2a, which was in the form of a shape containing six equal parts, with five being shaded. Q2b was in the form of a fraction, with both of these questions having shared the same meaning equivalence but not having surface similarity to the TS. Then Q3 was in the form of a decimal fraction, as 0.462, which appeared the same as the TS but did not have meaning equivalence with the TS. Finally, Q4 was in the form of a percentage (67%), which did not have surface similarity or meaning equivalence as the TS (Robutti et al., 2020).

Our interpretation of the teachers' MERLO item design is as follows: The development of teachers' meta-didactical praxeologies that guide teachers in designing MERLO would provide insight into learners' thinking skills about fractions; it will also allow teachers to identify learners' misconceptions of the topics. As the example shows, the learner is asked to identify statements in multiple representations that share the same mathematical meaning equivalence with the TS and describe the notion they had in mind when making the decisions. Thus, the MERLO item was combined with multiple-choice (recognition) and short answers (production). The two key scores, recognition and production, provide feedback to learners. In other words, the first score (i.e. recognition score) was based on identifying the statements that shared the same meaning among the five given statements, while the second score (i.e. production score) was based on writing out the reason that guided the answers for their decisions. This feedback is important to teachers since it provides information about their learners' level of understanding of specific conceptual knowledge. The production score of the MERLO test items was based on the clarity of the learner's explanation of the conceptual context anchoring the item, as well as the clear inclusion of lexical labels of relevant and crucial ideas and relations in that description.

Teachers followed the instructions on designing each statement of the MERLO item by using a TS as the opening question, which linked to the four other given items. The representation of the given items (i.e., Q2a, Q2b, Q3c, Q4d), which represents a shape, fraction, decimal fraction and percentage, is known as the "techniques." Scholars indicate that selecting items with the same mathematical meaning as the TS might be difficult (Robutti et al., 2016, 2020; Robutti, Prodromou & Aldon, 2021). This process guides participants to carefully design MERLO items questions. The participants shared their reflections at the end of the workshop training session, which is known as the "justification." These reflections were meant to provide us with the progress achieved in workshop training and the necessary information on whether any challenges needed to be addressed before adjustments to teachers' didactical praxeologies were considered (i.e., implementation).

After the teachers' meta-didactical praxeologies were adjusted and reviewed, the mathematics didactical praxeologies were implemented in the classroom which allowed learners to discuss and exchange ideas while considering a particular MERLO item, to share and contrast points of view, to remind and refresh each other about crucial details of the conceptual situation, and to "compare notes" about potential responses (cf. Phase 3).

Phase 3: Findings from Post-MERLO Participation (Implementation of Mathematics Didactical Praxeologies)

We conducted post-interviews and classroom observations and examined teachers' lesson plans and learners' worksheets after the participants had attended the MERLO workshop, and the following themes emerged.

Theme 1: Notions of MERLO and strategies used to support MERLO

Sub-theme 1.1: Teachers' understanding of MERLO

During the post-interviews, these views about MERLO were expressed. SCH1-MT1 said: "*MERLO is a method that helps the teacher to see how do the learners understand the content*." SCH1-MT2 mentioned: "*I think MERLO improves learners' ways of thinking and understanding and*

also to explore learners' level of understanding on that concept." SCH1-MT3 stated: "*MERLO is a teaching technique that allows us as a teacher to improve learners' understanding*." SCH2-FT2 said: "*It is a strategy that is used to help learners to understand mathematics more*." All teachers had changed their lesson plans after attending the MERLO workshop. One of the teachers mentioned:

> *When there are at least two correct answers, but you must say if this is correct, what is the difference between those two answers? And then, the learners can immediately understand that even though the content is different, they all have the same meaning.* (SCH1-MT1)

Before the MERLO workshop, teachers mostly used closed-ended questioning, but after the workshop they used more open-ended techniques. One teacher mentioned:

> *The changes that I have made in my original lesson plan could be offering more options to the learners to get an opportunity for them to answer questions because before, I was actually giving them questions that carried one answer but now giving them some questions that have different options whereby they choose answers.* (SCH1-MT3)

The participants' understanding of MERLO was consistent with the definitions provided in the literature (Arzarello et al., 2015; Robutti, 2015).

Sub-theme: 1.2: Strategic MERLO questioning

The teachers believed that presenting the MERLO questioning was easy, enabling learners to understand the concepts effectively. SCH2-FT2 explained: "*As I was circulating the classroom when the learners were writing the activities, I could see their answers, and their answers were on point. So, I could say I have reached my objective*." The teachers indicated that elicited evidence of learners' learning through MERLO questioning worked effectively during mathematical teaching concepts because learners were actively involved in the Q&A sessions. The active involvement of learners was also observed during the classroom observation. The teachers indicated that learners were motivated about the content of the lesson. SCH2-FT2 stated: "*It works well because I saw with the learners, they were fully participating they were asking questions, answering questions and were excited about the lesson*." Strategic questioning is important as it compels learners to participate and share their thinking and it promotes higher-order thinking (Steyn & Adendorff, 2020).

Sub-theme 1.3: Substantive MERLO feedback

During the classroom observations we observed that the teachers effectively checked for learners' understanding of the lesson. Also, the teachers did not only mark and score learners' worksheets, but they did effective corrections for the learners on the aspects that needed improvement. SCH1-MT2 responded as follows: "*After marking, I give my learners their papers back*." SCH1-MT3 mentioned: "*I give them some activity in class whereby I mark them*." SCH2-FT2 mentioned: "*Learners were given corrections of the work they have done*." One of the teachers said:

> *At the end of the learning activities, we did the corrections and then where we interacted with the answers again by showing the learners how they are supposed to answer it following the learners who got it right and the learners who could not get it right, they give them another chance to do it again by getting it right.* (SCH1-MT1)

The teachers expressed their purpose of providing feedback to the learners since they believed that giving feedback assisted learners in understanding the topic being taught before moving to the next level. The teachers also believed that providing feedback to learners allowed learners to see what they did not understand. SCH1-MT2 mentioned: "*For learners to see and have an idea of what they need to work on and what specifically needs to be addressed*." SCH2-FT2 stated: "*The purpose is to develop learners more so that they can see their mistakes and they do not repeat their mistakes again*." Continued feedback is important as it allows learners to better assess and monitor their own understanding (Watkins & Mazur, 2013).

Sub-theme 1.4: PASA

The teachers not only acknowledged the quality of PASA, but they also explained and demonstrated what MERLO entailed by giving learners opportunities to perform their self-assessment and classroom discussion effectively in the mathematics classroom. From the post-interviews, it was evident that the teachers believed that class discussion allowed learners to actively participate in the lesson, enhancing learners' level of understanding and thinking. They also believed that individual class activities helped learners identify whether they understood the lesson. The teachers' statements revealed a change of practice regarding individual class activities and a class discussion after participating in the MERLO workshop. SCH1-MT2 stated: "*I think class discussions are more effective because it is easier and practical when learners learn their mistakes from their classmates and someone far ahead of them as an adult*." SCH2-MT2 stated: "*I think group discussion is the most effective when planning because another learner will come up with examples to discuss in class*." Another teacher stated as follows:

> *I think the class-discussion activities because the class discussions the learners get to discuss among themselves. So, with class discussion, they can feed up each other information and then I, as a teacher, just come and guide the process and only correct the ones that are not correct.* (SCH1-MT1)

Wanner and Palmer (2018:1032) acknowledge that the move to PASA is "not simple for teachers and students but is worthwhile and necessary for twenty-first century higher education."

Theme 2: Impact of the application of MERLO as FA strategy

Sub-theme 2.1: Increased learner interest and motivation

The teachers observed that introducing and presenting MERLO to support FA activities inspired their learners to show interest in the lesson. SCH1-MT1 stated: "*When we are teaching, the learners are already paying attention to that, so they are already seeing and picking up the answer while still teaching*." SCH2-MT1 said: "*When you explained a new topic to them, but when you keep simplifying, then interest developed*." SCH2-FT2 stated: "*It works well because I saw that they were excited about the lesson. When I give my learners the activities, they were able to do those activities, and then they showed interest because they even asked further questions*." It is evident from the teachers' voices that when learners were excited because of the change in the mathematics classrooms, they developed more interest and motivation in their class.

Sub-theme 2.2: Active learner participation

From the post-interviews and classroom observations it was evident that learners were actively participating in MERLO activities. SCH1-MT2 declared: "*By the participation that the learners give when I give examples and questions, how responsive they were; it was quite good*." SCH2-FT2 said: "*With the learners, they were fully participating they were asking questions, they were answering questions*." The teachers also mentioned how classroom discussion equipped learners to be actively involved in learning, resulting in learners asking questions and interacting in class. SCH1-MT3 stated: "*I could say class discussion because it allows every learner to actively engage in a class*." It was evident from the teachers' comments that the learners had a cordial relationship with their teachers during lessons. The classroom observations confirmed that teachers did not ignore learners' responses; instead, they paid more attention to learners' responses and provided immediate and positive feedback to the learners. The class observations showed that the teachers created a conducive and respectful learning environment where learners could actively participate without having anxiety about it. The belief by teachers that greater learner participation lead to greater learner learning was not only indicated by the participating teachers but also in the literature (Triyanto, 2019).

Sub-theme 2.3: Deepen learners' understanding

SCH1-MT3 mentioned: "*I did with the assurance of the learners that they do understand by the question I was asking the learners; they end up giving me the correct answers*." SCH2-FT2 stated: "*To show now in the questions learners were asking, you could see they have the understanding*." Another teacher stated the following:

> *When they were doing the activities that we have given them after teaching them about MERLO. And then when I was working around and checking the learners of their progress, how they are writing what they are writing, I was surprised to see that most of them get it right, and then I remember by saying 'wow, this is easier more than I thought.'* (SCH1-MT1)

From the teachers' responses, it appears that learners had a practical understanding of the subject presented in the lesson. By moving away from calculations and procedures to rather focus on mathematical meanings (which is a feature of MERLO) (Robutti et al., 2021), learner understanding was deepened.

Sub-theme 2.4: Increased learner autonomy in learning

All the teachers revealed that using MERLO in support of FA activities increased learners' autonomy in learning. Additionally, the teachers underscored the importance of clarifying the purpose of schooling for learners, emphasising that students should not be perceived as passive receptacles but rather as engaged participants in their educational journey. One of the teachers gave the following response:

> *I think the climate is more learner-centred because as a teacher we try our best to make sure learners are engaged, make sure that we listen to them, and allow them to give what they know before as a teacher are then giving information to them. So, we want to know what they come with as we already know that they are not an empty vessel. So, we are trying our best to make it more learner-centred.* (SCH2-FT2)

The classroom observations confirmed the teachers' responses regarding learner autonomy. It was observed that during the Q&A session the teachers asked the questions and the learners responded. Teachers asked learners to give the reasons that guided their answers; most of the learners were able to grasp the concept. This outcome implies that teachers planned their lessons and designed MERLO questions effectively, which led to asking open-ended questions that stimulated learners' interest and confidence. The open-ended questions moved the focus away from calculations and procedures to mathematical meaning, which is a feature of MERLO (Robutti et al., 2021).

Theme 3: Challenges in implementing MERLO strategies

Sub-theme 3.1: Continual support required

Although the implementation of MERLO in support of FA activities was successful, the post-interview findings reveal that teachers experienced some problems when implementing MERLO in the mathematics classroom. The challenges that were pointed out linked to the way in which teachers presented and explained MERLO. One of the teachers mentioned the following: "*Following a*

proper step was a bit difficult because sometimes, you know, the order can easily be forgotten. So, there is a specific order to follow when doing the presentations, but I used my workshop guide to remind myself" (SCH1-MT2).

SCH2-MT2 stated: "*At first you know when you do not understand MERLO, it seems like it looks difficult, but once you understand it, you will see that it is the simplest and effective way of teaching*." These viewpoints were supported by a teacher who added:

> *The challenge was, in the beginning, to understand what it is about because it was something new which we have not seen before. And having gone through 4 years of university and seeing all the different pedagogic approaches, this one was new, and then when I saw it, my first question was, 'where is it coming from? Is it Piaget or is it one of the old scholars'? But then I realised that 'no' it is something new then the more I read about it, the more I understood it.* (SCH1-MT1)

As triangulation, the classroom observations confirmed the challenges that the teachers had expressed in the post-interviews as we observed that teachers found it difficult to explain some of the MERLO terminologies in the beginning, for example, what was meant by "target statement" and "surface similarity." More so, it was observed that teachers at times forgot to mention the MERLO target statement during Q&A sessions. One of the teachers mentioned the following:

> *The challenge was clearly explaining the target statement, as I saw during the lesson when the learners were answering; when they are to now pick the answer that relates to the target statement, they were also ticking the target statement. So, it might not have been clear to them that the target statement is more like an opening question. So whatever answer you are going to tick, you do not tick the target, but you tick something that relates to the target statement. So, clarity of the target statement was my challenge.* (SCH2-FT2)

Not only did the teachers request continued support on new techniques but it is also indicated as necessary in the literature (Keiler, 2018).

Limitations of the Study

This study was subjected to various limiting conditions common to qualitative PAR methodologies, such as the fact that researcher subjectivity and bias can negatively affect a study. We ensured our neutrality by detailing all the steps taken during data analysis and being aware of the risk of bias. The latter was accomplished by conveying a feeling of acceptance of the participants – of what they answered (to avoid participant bias). We also entered the process with an unbiased mind by ensuring that our pre-existing assumptions were kept at bay (to avoid researcher bias). Another problem was the lack of literature on MERLO pedagogy used in FA activities in a South African context. Consequently, we reviewed studies conducted on MERLO pedagogy in other countries. It must further be acknowledged that the findings of this study are based on a limited sample of teachers and schools, which has implications for the transferability of the results. The person who wishes to "transfer" the results to a different context should be held responsible for judging how sensible such a transfer would be. A collective gathering of teachers from different schools to share their experiences and challenges in their various classroom contexts would have been preferred, however, due to the COVID-19 pandemic, we trained the teachers at their different schools.

Conclusions and Recommendations for Future Research

The change in teachers' classroom practice with MERLO pedagogy being used for FA activities in the T&L of mathematics stimulates learners' autonomy, promotes learners' mathematics attainment, which will, ultimately, improve learners' mathematics performance. The findings from this study could guide professional development programmes of teachers in T&L and assessment of mathematics education. Due to the small number of teachers who participated in this project it is recommended that more South African teachers are involved in MERLO professional development. The authors plan to conduct follow-up studies with the participants of this study to determine the effect of their ongoing practice of MERLO on learners' performance in mathematics and to determine whether they were still experiencing challenges in using MERLO strategies in their classrooms. Due to the challenges already highlighted by the participants, it is recommended that once teachers have been introduced to a new technique such as MERLO, there should be continued support provided to those teachers. International researchers are already working on the topic of learning in the digital age using MERLO (Shafrir, 2020), and a similar study should be conducted for FA strategies using MERLO in the context of modern information technology such as electronic learning (e-learning) platforms and technology-based learning within a South African context. Globally MERLO is already applied in other subjects (cf., e.g. Kenett, 2021, who applies it to statistics and data science education), and future studies could involve training South African teachers in MERLO strategies for subjects other than mathematics.

A study could be conducted on pre-service teachers in teacher education, mathematics education, and science education institutions to initiate the MERLO pedagogy in their teaching practices and perspectives, and investigate the effect on pre-service teachers' training in educational institutions. A study could be conducted to determine learners' perceptions of MERLO

pedagogy supporting FA activities in mathematics classrooms and whether they feel that the introduction of MERLO has promoted their conceptual thinking and understanding of mathematics. Findings from this study could direct the development of the instrument for teachers and learners to enhance learners' attainment and classroom practice. MERLO questions may have a place in post-school education. Thus, suggesting MERLO questions in post-school education could enhance learners' progression of conceptual understanding with variations between concepts.

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Authors' Contributions

MAG conceptualised the idea and LOA conducted the field work and collected the data. Both MAG and LOA were responsible for analysing the data, writing up the results and finalising the manuscript.

Notes

i. The study consisted of three phases; Phase 1 (pre-MERLO participation), Phase 2 (MERLO participation) and Phase 3 (post-MERLO participation).
ii. During Phase 1, the COVID cases in South Africa were under control (i.e., the country was on a low level of lockdown), however, during Phases 2 and 3 of this study, the number of COVID cases had increased so drastically that South Africa was at a higher lockdown level and some teachers were reluctant to continue with the project as it involved in-person meetings.
iii. SCH represents the school SCH1 = School 1; six schools (SCH1–SCH6) were involved.
iv. MT and FT represent male teacher and female teacher respectively.
v. Phase 1 of this study was undertaken during a period when the COVID numbers in the country were under control.
vi. This article is based on the doctoral thesis of Lydia Omowunmi Adesanya.
vii.
viii. DATES: Received: 6 September 2021; Revised: 18 July 2022; Accepted: 20 January 2023; Published: 31 August 2023.

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Appendix A: Creation of MERLO Items

Generally, MERLO items are made up of five statements, namely, an unmarked target statement (TS) and four other statements (also unmarked) that are developed as follows: shared equivalence of meaning with TS (i.e., a commonality of meaning across several representations) and/or shared surface similarity with TS (i.e., looks similar by sharing the same sign system, but not the same meaning), or neither of the aforementioned (Etkind et al., 2016). It is possible to divide statements into four quadrants (Q1, Q2, Q3 and Q4) related to the TS. Q1 contains statements similar in appearance to TS that share the equivalence of meaning with it. Q2 contains statements that are not similar in appearance to the TS but shares equivalence of meaning with it. Q3 contains statements similar in appearance to the TS but which do not share the equivalence of meaning with it. Q4 contains statements that, although thematically relevant to TS, are not similar in appearance to the TS, and do not share equivalence of meaning with it. Etkind et al. (2016) recommend that Q1 statements be excluded as they are extremely straightforward. The four quadrants are summarised in Table A1.

Table A1 Summary of the quadrants (adapted from Robutti et al., 2020)

Quadrant	Meaning equivalence with TS	Surface similarity to TS
Q1	Yes	Yes
Q2	Yes	No
Q3	No	Yes
Q4	No	No

Scholars indicate that MERLO pattern design is categorised into two criteria: meaning equivalence and surface similarity (Arzarello et al., 2015; Robutti et al., 2016, 2020, 2021). However, meaning equivalence is a statement that shares the same mathematical concept with the target statement, while surface similarity is a statement that appears the same as the target statement but does not share the same meaning with the target statement (Arzarello et al., 2015; Robutti et al., 2016, 2020). The first score (i.e. recognition score) is based on identifying the statements that share the same meaning among the five given statements, while the second score (i.e. production score) is based on writing out the reason that guided the learners' answers. This feedback is important to teachers since it provides information about their learners' level of understanding of specific conceptual knowledge. The production score of MERLO test items is based on the clarity of the learner's explanation of the conceptual context anchoring the item, as well as the clear inclusion of lexical labels of relevant and crucial ideas and relations in that description.

Appendix B: Conceptual Framework for this Study

Figure B1 illustrates the conceptual framework for this study.

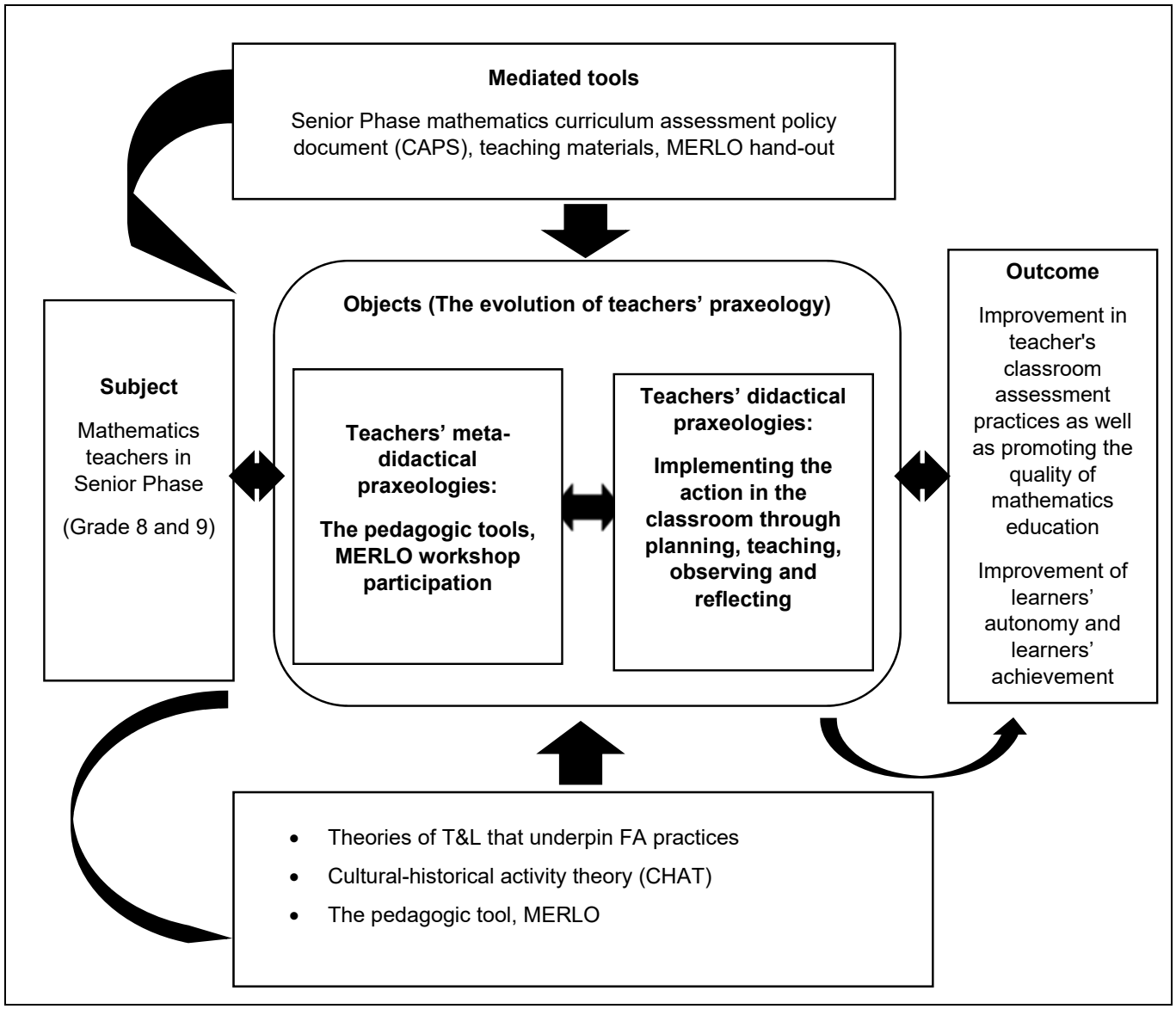

Figure B1 Conceptual framework for the study

The Mediated Tools

In the activity system perspective, the mediators of the object-oriented activity (being the tools) may be considered as the policy regulations that teachers need to follow in the FA activities of mathematical concepts. This policy document includes the guidelines, planning and content areas of mathematical concepts. In addition, policy documents cover the recommended textbooks for Senior Phase mathematics for both teachers and learners, the pre-service and in-service professional development training to support mathematics teachers to implement the implementation of FA activities and strategies in the mathematics classroom.

The Subject

The subject represents the Senior Phase (Grades 8 and 9) mathematics teachers. Teachers play a critical role in the practice of FA activities. Teachers are responsible for preparing lesson plans and facilitating learners at all levels. Their duties include designing FA activities that stimulate learners' previous knowledge and support learners' participation in their lesson activities. Teachers need to use diagnostic assessment to determine learners' strengths and weaknesses, knowledge, and skills prior to instruction to teach mathematical concepts. Teachers

need to improve learners' prior knowledge by asking open-ended questions about the subject. Teachers should also determine learners' skills and current knowledge with or without any assistance (Zone of Proximal Development; Vygotsky, 1978). All these activities are intended to support teachers in fostering instructional scaffolding activities to help learners understand the relevant concepts and enhance their learning and achievements.

The Objects: The Evolution of Teachers' Praxeologies (i.e., Teachers' Meta-didactical and Didactical Praxeologies)

This process refers to the teachers' actions, knowledge, participation and training developed to improve the effectiveness of FA activities and strategies in the classroom (Robutti et al., 2020). Teachers are responsible for selecting the recommended books and teaching methods to effectively implement FA activities based on mathematical concepts and content areas to reach the desired learning objectives and outcomes. To effectively implement FA activities, there is a need to determine and observe teachers' understanding of strategies that support FA activities in mathematics classrooms. After investigation, teachers need support to address the problems identified.

In the context of our study, the pedagogical tool, MERLO, used for FA activities could be used by participants based on the evolution of teachers' praxeologies such as teachers' meta-didactical and didactical praxeologies, even if teachers did not fully understand the FA and strategies that support learners' learning. During the process of the MERLO training workshop, the theories of T&L that underpin classroom implementation for FA were discussed. These theories, which support FA practice and strategies, are meditated into the interdependent relationships of the model indicated in Figure B1.

Nevertheless, teachers must receive continued professional development that could enhance their knowledge and skills to promote the quality of T&L (Andersson & Palm, 2018; Bernadine, 2019; Robutti et al., 2020). Developing and strengthening teachers with new knowledge and skills requires effective meta-didactical and didactical praxeologies (Robutti et al., 2020). The evolution of teachers' praxeologies (i.e., teachers' meta-didactical praxeologies of MERLO) were planned in dialogue with the teachers. Following the pedagogical tool MERLO training workshop, teachers were able to integrate MERLO questions across a sequence of a lesson plan which could be put into practice in their classroom (i.e., teachers' didactical praxeologies). The classroom implementation would have been facilitated by the teachers' didactical praxeologies (Robutti et al., 2020) to enhance learners' conceptual understanding (Arzarello et al., 2015). Face-to-face discussions with the participating teachers allowed them to share and reflect on the strengths and challenges with regard to their implementation (Arzarello et al., 2015; Robutti et al., 2020). The process of subjects working towards an object by utilising the mediators of the object-oriented activity (being the tools) brings about an outcome, and the process was observed effectively.

The Outcome: Improvement in Teachers' Classroom Practices; Promoting the Quality of Mathematics Education; Improvement of Learners' Autonomy and Learners' Achievement

The system activity represents the end result that fosters or impedes teachers' participation in future activities. Arzarello et al. (2015) indicate that the use of the pedagogical tool, MERLO, for FA activities by teachers could be improved if active workshop training support was provided for teachers. In this model, after the involvement of the evolution of teachers' praxeologies (i.e., teacher's meta-didactical and didactical praxeologies), the expected outcome was an improvement in teachers' classroom practices, promoting the quality of mathematics education; improving learners' autonomy and achievements in mathematics. There was an expectation that effective feedback to learners regarding teachers' classroom changes when teaching mathematical concepts might elicit teachers to reinforce and widen their practice of FA activities (Dini, Sevian, Caushi & Orduña Picón, 2020). The model anticipates that as teachers persist in the effective implementation of FA activities and strategies, it will result in improved learner autonomy in learning and academic performance (Dini et al., 2020; Furtak, Ruiz-Primo & Bakeman, 2017; Wiliam, 2013). According to this conceptual framework, the outcome reflects an improvement in the effectiveness of Senior Phase mathematics instruction.