Teacher Professional Development for the Teaching of Mathematics: MERLO Items Design in the South African Schools

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Abstract

Meaning equivalence reusable learning objects (MERLO) artefacts are a new type of didactical tool that can be framed by teachers and utilised in the classroom to engage learners in rigorous mathematical reasoning, discovery, and discussion. Before MERLO can be successfully implemented in classrooms, teachers must get training on it. MERLO has evolved and has been validated, tested and implemented across different countries (Australia, Canada, Israel, Italy, Russia and the Netherlands) and across various content areas and disciplines, but not yet in African countries until this study. South African mathematical teachers were introduced to the pedagogical tool, MERLO, as an assessment strategy to promote and support teachers' professional growth in using assessment practices in the classroom. The Meta-Didactical Transposition (MDT), a theoretical model for teacher education programmes [1], was used, and the study investigated how teachers engaged in professional development using the MDT framework, which gives an interpretative model of teachers' praxeologies. The study adopted qualitative participatory action research as it seeks to bring together action and reflection, theory and practice, and collaboration with others on practical solutions to issues of concern to individuals and their communities. Reporting on the professional development of the teachers is only a part of a larger study; another part of this study has been reported on by [2], which involved gaining insight into South African teachers' beliefs and practice of effectively communicating learning intentions and success criteria to their learners. This current study contributes to the body of knowledge as it introduced South African teachers to a new assessment strategy to promote and support teachers' professional growth in using assessment practices in the classroom. Due to the fact that COVID-19 prompted several teachers to withdraw from the study, leaving only five teachers in the end, future research should involve more teachers in similar studies. The study further advised that teachers in various nations should be supported in an intensive professional training programme on the MERLO approach. Future studies will include creating an online professional development course in MERLO to reach more South African teachers.

Keywords: *teacher professional development, assessment, mathematics education*

1. Introduction

The need for educational change has been persistent as education systems worldwide strive to meet evolving societal demands [3]. In South Africa, a growing awareness of the need for a better understanding of the complex problems we face, as well as the need to fully utilise accessible knowledge to develop better results, has become a great concern in evidence-informed policy and practice in the educational settings [4]. Professional development (PD) is widely acknowledged to be important in ensuring that teachers are core components of a skilled and current profession [5]. Studies have revealed that PD has not effectively achieved changes in teacher assessment practices, particularly in mathematics education [5-6]**.** The 2019 Trends in International Mathematics and Science Study (TIMSS) report indicates that South African senior phase learners performed poorly in mathematics, which causes serious concern [6]. Given the overwhelming evidence of poor achievement, according to the results of the TIMSS 2019, it is substantial to improve the efficacy and efficiency of teaching, learning, and assessment. More so, teaching effectively in the classroom is a critical goal for both teachers and educational researchers.

Meaning equivalence (ME) is a concept that represents shared meaning across different forms of representation. MERLO artefacts are a new type of didactical tool that can be framed by teachers and utilised in the classroom to engage learners in rigorous mathematical reasoning, discovery, and discussion. MERLO items require teachers to categorise and map significant concepts using sample target statements from certain conceptual contexts and relevant phrases that may or may not share

the same ME. Before MERLO can be successfully implemented in classrooms, teachers must get training on it. MERLO has evolved and been validated, tested and implemented across countries (Australia, Canada, Israel, Italy, Russia and the Netherlands) and various content areas and disciplines, but not yet in African countries until this study. Senior phase (Grades 8-9) South African mathematical teachers were introduced to the pedagogical tool, MERLO, as an assessment strategy to promote and support teachers' professional growth in using assessment practices in the classroom. The Meta-Didactical Transposition (MDT) framework was used to investigate how teachers engage in PD which gives an interpretative model of teachers' praxeologies [1]. The current study adopted qualitative participatory action research as it seeks to bring together action and reflection, theory and practice, and collaboration with others on practical solutions to issues of concern to individuals and their communities [7]. Two researchers and five senior phase mathematics teachers in South African schools were involved in the MERLO PD. The exploratory study focused on how mathematics teachers can design MERLO items in South African contexts. The study adopted the procedure from [8] to guide the effective dialogue and facilitation of the MERLO PD. The data was thematically analysed in practical components of the praxeologies (i.e. task and techniques), as well as the theoretical components of teachers' praxeologies (i.e. theory and technology) to justify their steps about designing the MERLO assessment items.

2. The Practical Component Task

Teachers were introduced to ME, representation of concepts, steps and some examples of the MERLO assessment items. Furthermore, the MERLO pedagogy could be justified by the theoretical components of various theoretical frameworks and aspects [8-9]. This 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, how MERLO items are designed with the support of providing teachers with a MERLO hand-out. The context of the discussion elucidates how teachers could be supported to design MERLO items. During this component (i.e., task), the teachers collaborate with the researchers to prepare and design MERLO items for teaching and assessing mathematical concepts.

3. The Practical Component: Technique

This section describes a MERLO item's design process in sequential order of TS-Q2-Q3-Q4. According to [10], statements can be divided into four quadrants (in short, Qs) (Q1-Q4) that are related to the target statement (TS) because the relevance of the Qs with the TS tries to identify learners' needs in learning, which provides teachers with opportunities to pay close attention to how they plan their lesson and how effective a good question is designed for mathematics education. [10] urge that Q1 statements be avoided since they "give away the common meaning due to the valence match between surface similarity (SS) and ME, a strong indicator of shared meaning between a Q1 and the target statement" (p.318). Figure 1 portrays the MERLO item framework used to design MERLO questions, and we discussed and explained this template to the teachers.

Figure 1. MERLO item framework

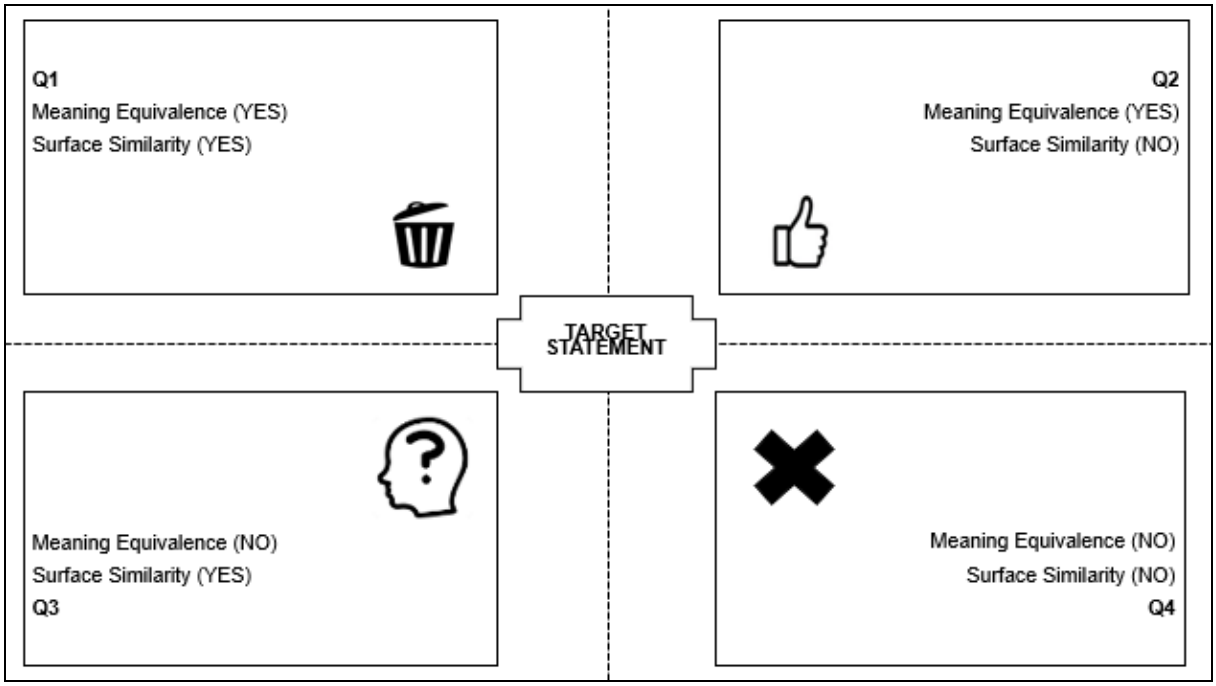

Figure 2 shows an example of a teacher's MERLO item with the topic "exponent".

Figure 2. MERLO item example

Instructions	TS	Q2
1.Mark all statements that share the same mathematical meaning 2.Write down your thought that guided your decisions	A [ ] Exponent 2^2	B [ ] Whole number 4
Q2	**Q3**	**Q4**
C [ ] Multiplication 2 x 2	D [ ] Exponent 2^b	E [ ] Number line 

4. Theoretical Component: Technology and Theory

This section analysed the justification of the task and the techniques (i.e., practical component). After designing MERLO items, teachers shared their knowledge and justified the reason that guided their chosen answers. Teachers shared ideas with other teachers by explaining that the MERLO question was designed on the topic "exponent" (Figure 2), which represents the TS "2^2" and, by showing that there are other ways of expressing numbers instead of writing the numbers, you can also express them in the form of exponents. The first Q2 statement (Cell B) represents a whole number of "4"; the second Q2 statement (Cell C) represents the multiplication of "2×2", which shows 2 can be multiplied

by 2 to get the answer of 4. Teachers acknowledged both these Q2 statements shared ME with TS but not SS. Teachers demonstrated that representation requires learners to identify the Q2 (there can be more than one Q2 statement) that shares ME with TS. Then the learners should give reasons that guided their choice of decisions. The teacher further interpreted the choice of the Q3 and Q4 statements. The Q3 statement (Cell D) represents the exponent of "2^b" which has SS with the TS of "2^2" but not ME. The Q4 statement (Cell E) represents a number line from 0 to 8 with a cross at the value of 3, however it doesn't SS or ME with the TS. The illustration implies that teachers' designing of MERLO items could assess learners' conceptual understanding and thinking skills in the mathematics classroom, and the Q3 and Q4 statements are a form of distractors and guessing. The illustration further implies that the development of teacher meta-didactical praxeology that guides teachers in designing MERLO would provide insight into learners' thinking skills when solving the form of exponents; it will also allow teachers to identify learners' misconceptions of the topics. It can also be used as a form of formative and summative assessment in education.

5. Conclusion

The study aimed to develop teachers' competencies to design MERLO items to transform their classroom practice. Teachers showed great interest in incorporating MERLO pedagogy and had the opportunity to share their perspectives and insights before and after the workshop. These reflections aimed to identify challenges faced by teachers in their professional practices. The data presentation revealed the involvement of mathematics teachers in the workshop training. Initially, teachers faced difficulties designing MERLO items, but with consistent practice during professional development, they became proficient in creating such questions. Furthermore, teachers were able to identify students struggling with mathematical concepts and demonstrated a strong understanding of MERLO pedagogy, making necessary adjustments when designing MERLO questions. We observed that the practical components of task and technique in designing MERLO items facilitated open interaction among teachers. This reaction aligns with previous researchers' findings [8, 11]. The process of designing MERLO items had a positive impact on students' math performance when effectively integrated into the classroom. However, due to COVID-19, the study had a limited sample size of five teachers, suggesting the need for future research with more participants. The study recommends providing intensive professional training on the MERLO approach to teachers in different countries. Additionally, future studies aim to develop an online professional development course in MERLO to reach a wider audience of South African teachers.

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