

Invited Lecture

Proposed Pedagogical Content Knowledge Tool for Assessing Teachers' Proficiency in Mathematical Knowledge for Teaching

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ABSTRACT Studies have indicated that the development of Mathematical Knowledge for Teaching (MKT), is rooted in teaching experience occasioned in teachers' daily work. To determine the role of teaching experience in the development of MKT, a special tool was required to capture all the MKT tenets and their combinations for analysis of mathematics teacher's proficiency. In this article the effectiveness of a tool developed purposely to examine the relationship between years of teaching experience and the development of Mathematical Knowledge for Teaching (MKT) is shared. This article has been drawn from a larger study on MKT proficiency status carried out in Kenya involving 117 trained secondary school mathematics teachers with varying years of teaching experience and academic backgrounds. Both descriptive and inferential statistics were found to be interpreted accurately using this tool. Using this tool, this study found a very weak positive relationship ($\beta = 0.171$) between teaching experience and MKT proficiency. The study established that MKT proficiency is not progressive, it is non directional and can regress in spite of teaching experience. From this finding it is my proposition that this pedagogical tool can sufficiently be used to discuss exhaustively teachers' MKT proficiency.

Keywords: MKT; PCK tool; Teaching experience; PCK proficiency.

1. Background and Context of Study

Mathematical knowledge for teaching (MKT), the mathematical knowledge that is specifically useful in teaching mathematics, is claimed to have its development deeply rooted in the experience afforded to teachers in their daily work (Ball, 1993). Proficiency in MKT is described as the deep connected understanding of mathematics as a subject and the flexible knowledge about effective strategies of presenting mathematical content to learners (Ball 1993). The extent to which MKT is refined by years of experience has not been well documented. This article shares a Proficiency Status Tool (PST) (Miheso and Margot, 2016) that can quantify qualitative data for exploration and determination of teachers' MKT proficiency. The process of using the tool includes examining each component of the framework (see Fig. 1) adapted

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from Ball et al. (2008). In this paper, the efficacy of this proficiency status tool is applied to measure the relationship between teachers' MKT proficiency and teaching experience.

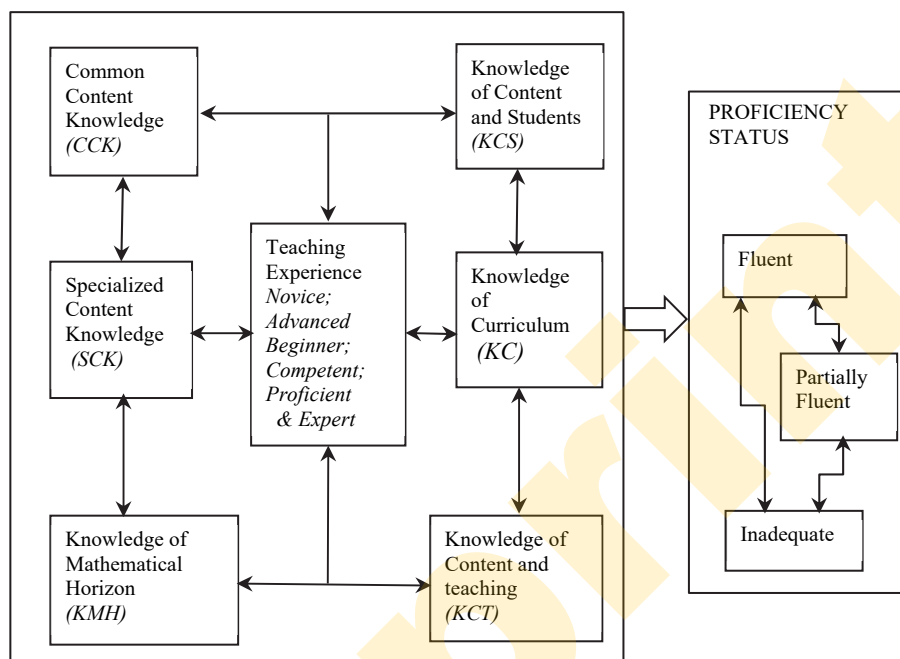


Fig. 1. Conceptual framework: MKT proficiency development process by experience

According to Ball (1993), the development of MKT, an accumulation of a defined body of knowledge, is deeply rooted in the practise of teaching. Accordingly, the proficiency tool was applied on the practice of teaching to investigate proficiency status of teachers' MKT in the Kenyan context. The study combined the teaching experience categories using the novice–expert (Livingstone and Borko 1989) model, the Mathematical Knowledge for Teaching (MKT) framework developed by Ball et.al (2008) and the study's generated MKT rubrics to develop the proficiency status tool.

The proficiency status tool is a descriptive model that quantitatively characterizes teacher's proficiency on a continuum of fluent, partially fluent and inadequate. For this study, (i) *Proficiency Status is Fluent* represents a status in which teachers' transformation of content into comprehensible concepts for learners is powerful and easily discernible; (ii) *Proficiency Status is partially fluent* describes the status where the teacher displays good content mastery (CCK) and acceptable basic pedagogical strategies and procedural text guided knowledge of student as a learner. Teachers at this level drift within the Novice — Expert stages of; advanced beginner, competent and proficient professional intermittently at various stages of curriculum implementation. The status category' (iii) *Proficiency is inadequate*' is characterized

by observable teacher's insufficient MKT competency. The teacher is textbook dependent, uses textbook worked examples. Teachers within this category facilitate a learning environment that is passive (KCS).

Based on these descriptors, this tool was used to determine the relationship between years of teaching experience and teacher's proficiency status in Mathematical knowledge for teaching. A mixed methods approach was adopted to profile teacher's proficiency status of MKT and then map these status categories to their teaching experience. The main assumption of the study was that, Mathematics teachers' proficiency status in MKT is dependent on the cumulative proficiency of its components as described in MKT model (Ball 1993). Experience by number of years was regressed against these variables to determine the significance of this relationship.

2. Developing the Pedagogical Status Tool (PST) Using MKT Rubrics.

A generic rubric guideline for the written tasks was first developed using a numeric value (0 to 4) assigned to progressive competency descriptions based on MKT problem solving typical memo as displayed in Tab. 1 below.

Tab. 1. Generic MKT Rubric

Score	Description
0	No response, incoherent explanation, wrong response
1	Partial incomplete interpretation, explanations that fault correctly identified prerequisite knowledge without justification
2	Correct interpretation of student action without explanation
3	Correct interpretation of student action with clear correct explanations
4	Correct interpretation, clear explanation, evidence of powerful pedagogy through use of analogies, correct remedial response

Based on this generic rubric guide, a specific MKT 5- point rating scale ranging from; correct response, partially correct (2 levels), incorrect and no responses was adapted for each task item in the teacher's pedagogical questionnaire. In addition, for this study, three proficiency categories (Tab. 2), fluent, partially fluent and inadequate were bench-marked using mean scores and categories to interpret the scores generated using the rubrics. The lower and upper limits for each category was generated based on the general performance, teaching culture of study location, what provides for a proficient teacher based on literature and the authors professional experience with teacher education.

Tab. 2. Bench-marking Proficiency Categories

Proficiency Categories	Fluent	Partially fluent	inadequate
Competency benchmarks by mean score	$4 \geq M \geq 2.5$	$2.5 \geq M \geq 1$	$M \geq 1$

2.1. Analyzing data using PST

To measure MKT proficiency, each task was broken into MKT components and strand types. (Tab. 3) Mean scores were then determined for each task from teacher scores.

Findings indicate that tasks with a combination of higher cognitive MKT components such as knowledge of Mathematical Horizon (KMH), Specialized Content Knowledge (SCK) returned poorer scores than those that demanded Common Content knowledge (CCK) and Knowledge of Curriculum (KC). These findings reveal that experience as a stand-alone determinant does not sufficiently explain teachers MKT fluency.

Tab. 3. Task MKT Components Mean Score tool descriptors

Item no.	MKT Knowledge assessed	Task strand	Mean (max=4): SD	Proficiency descriptions
1	CCK, KCS, KCT, SCK, KMH, KC (6)	Data handling/Number /Operations	1.1(1.09)	Partially fluent
2	CCK, KCT, SCK, KMH (4)	Algebra, Geometry	1.6 (1.04)	Partially fluent
3	CCK, SCK (2)	Number and Operations	0.92 (1.4)	Inadequate
4	KCS KCT, CCK (3)	Algebra	0.56 (0.94)	inadequate
5	SCK, KCS, KMH, CCK (4)	Measurement/Geometry and Algebra	1.3 (1.2)	Partially fluent
6	CCK KCS, SCK, KMH (4)	Algebra/Geometry	1.18 (1.08)	Partially fluent

Teacher's performance on specific MKT components to determine respective fluency for each knowledge type indicated that fluency level of proficiency was determined in the KCT component of MKT (Tab. 4).

Tab. 4. Status of Performance Levels by Knowledge Type

Pedagogical knowledge type	Mean score (Max. score 4)	Rating
Common Content knowledge	2.5	Partially fluent
Specialized content knowledge	0.98	Inadequate
Knowledge of Content and Student	0.97	Inadequate
Knowledge of Mathematical Horizon	0.63	inadequate
Knowledge of Content and Teaching	3.5	fluent
Knowledge of Curriculum	2.0	Partially fluent
OVERALL SCORE FOR MKT	1.76	PARTIALLY FLUENT

Fluency in KCT which is teachers knowledge of content and teaching is a strong indicator of the type of knowledge that is the most impacted by years' experience

The tool afforded returns of a mean score in KCS (0.97), SCK (M = 0.72), This finding which is described in the MKT proficiency status tool as *inadequate* is a strong indicator of a content-based teaching approach with minimum student support. The results also reveals partial fluency were attained in some items. Based on these results several interpretations and recommendations were made possible from this analysis

2.2. Using PST to measure MKT performance by years of experience

When teachers performance on tasks was compared by years of experience on each of the tasks, an average mean score of 1.11 against a maximum score of 4 was found. The study showed consistently higher performance for the competent and proficient

categories in comparison to the novice and expert categories completely flipping the experience by years stage model by Dreyfus and Dreyfuss (1989) and Novice expert model by Livingstone and Borko (1986).

When a regression of performance on the cumulative mean scores for each category with categorized years of experience was carried out, a result ($\beta = .171$, $F = 1.857$, $p = 0.66$) was found. This indicated a weak positive relationship and in addition the relationship was found to be not statistically significant.

3. Conclusions

The MKT tool can be used to provide a more detailed evaluation of teacher's MKT proficiency across all the mathematical strands. Findings from this study which revealed an overall partially fluent proficiency status ($M = 1.76$), suggest that teachers' schemata require focused efforts on teachers' knowledge to support their systematic progress towards fluency in MKT. Using PST, it was possible to determine the non-statistically significant relationship ($\beta = 0.171$) between proficiency status and teaching years of experience. This finding reveals that mathematics teachers, irrespective of experience, have inadequate proficiency status in the KMH component of the MKT framework.

Teaching mathematics at secondary school requires deep understanding in all the strands offered at this level. Variation in proficiency status across strands was revealed indicating skewed teaching experience. It was possible through use of the PST to determine similarities in both the less experienced teachers and the more experienced teachers in their proficiency displays of MKT. This relates to the characterization of the KCS and SCK components ($M = 0.98, 0.97$) as a need effort of all the MKT components. Inadequate display of proficiency levels in three categories from both most experienced and less experienced teachers refutes a direct relationship between experience and proficiency levels in MKT. This study revealed that the ability to refine and support student understanding as they engage in problem solving require purposeful targeted experiences.

Consequently, this study concludes that the role of experience by number of years should not be used to explain the proficiency status of teachers, but experience should be used to support the development of proficiency among mathematics teachers.

Teaching Mathematics at secondary school level is a complex process, but teachers can be supported to develop their fluency levels in MKT. Through the findings, Using PST, It is possible that MKT components that display low proficiency among secondary school teachers can be targeted for professional developing. This would help develop focused and relevant programs that address the MKT that teachers need to develop their teaching knowledge. This would make experience of the practise of teaching a resource for proficiency development of MKT.

This article posits that it is possible to quantify MKT for a deeper analysis of the deeply interwoven web of MKT components present in the daily tasks that teachers encounter in their work of teacher using Proficiency Status Tool (PST). Accordingly,

teachers' needs can be addressed through determining their general and specific MKT proficiency using this tool

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