University of Szeged

Doctoral School of Education

Learning and Instruction Programme

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Formative Assessment as an Instructional Approach in the Teaching and Learning of Mathematics: A Case of Secondary School Teachers and Students in Kenya

Summary of the Dissertation

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Szeged, Hungary, 2022

The Context and Structure of the Dissertation

Context of the Study

Kenya is among the countries adopting the Competency-Based Curriculum (CBC). For the successful implementation of the CBC in Kenya, there is a need to equip teachers with the skills and tools required to carry out formative assessment in classrooms. Teachers need to embrace instructional approaches that will enable learners to engage in lifelong learning. Mathematics teachers are specifically taxed with ensuring that students make sense out of mathematics concepts and relate them to authentic situations. Teachers' perceptions, competencies, and practices are therefore crucial in determining the realization of competence-based learning.

The findings by the task force (Republic of Kenya, 2012) revealed that the current summative assessment in the Kenyan education system falls short of adequately measuring learners' abilities and teachers lack adequate training on alternative assessments. There has been a continuous decline in mathematics performance in Kenyan secondary schools over the years despite the interventions that have been put in place (Wafubwa & Obuba, 2015). Among the intervention programmes being carried out in secondary schools, none has focused on formative assessment.

The present study first examined mathematics teachers' perceptions of formative assessment and their levels of metacognitive awareness. Secondly, a formative assessment intervention study was carried out to determine the impact of formative assessment on students' achievement in mathematics and metacognition. The overall aim of the study was to assess the preparedness of secondary school mathematics teachers in implementing a competency-based curriculum and to suggest the best formative assessment practices that can be used in mathematics classrooms. It's hoped that the findings of this research will contribute knowledge towards the development of an assessment framework in mathematics instruction for secondary schools in Kenya.

Structure of the Dissertation

This dissertation is composed of five chapters. Chapter one gives an introduction of the study focusing on the context, problem statement, significance, and an outline of how the dissertation is structured.

Chapter two is a review of literature on studies related to the research topic. The main focus was on formative assessment and the teaching and learning outcomes. The review was based on the theoretical framework of formative assessment by Black and Wiliam (2009). The five strategies of formative assessment were systematically reviewed and the results showed that formative assessment can improve teaching and learning. The review also pointed out the need for more experimental studies on the impact of formative assessment.

Chapter three gives the aims, research questions, hypotheses, methods, and the synopsis of the empirical studies that are fundamental to this dissertation. Methodologies used in the studies focus on design, sample and sampling procedures, data collection procedures, instruments, and their validations.

Chapter four presents the five empirical studies which have been compiled from five separate journal articles. Study one assessed the suitability of the adapted teacher assessment for learning questionnaire in the Kenyan context. Study two examined the relationship between formative assessment and mathematics teachers' metacognitive regulation. Study three looked at teachers' conception and perceptions of their metacognitive awareness. Study four involved the construction and validation of a test to measure students' proportional reasoning skills in mathematics whereas study five examined the impact of formative assessment on students' achievement in mathematics and their metacognitive awareness. Chapter five is the final chapter which gives the conclusion and recommendations of the research followed by the list of references and appendices.

Theoretical Background

The current research was informed by Black and Wiliam's (2009) framework (Table 1). The role of the three agents (teacher, peer, and learner) and five strategies of formative assessments in the learning process portrayed in the framework are discussed as follows:

The Three Agents

The three agents are the teacher, peer, and learner who act as partners in the learning process. Formative assessment involves the teacher as the primary actor and students as partners. Black and William (2009) described the formative assessment process as a cycle in which a teacher is continually asking a series of three questions: Where are my students headed? Where

are they right now? How can I close the gap between where they are and where I want them to be? The teacher's role involves identifying learning goals for the learners and then identifying where the learners are regarding those goals. The idea of closing the gap is achieved through timely, specific, corrective feedback; adjustments to instruction; and engaging peers in the support process.

Teachers' roles emphasize setting clear goals, making aspects of success explicit, providing useful feedback, and encouraging peer and self-reflection (Boud & Falchikov, 2007; Spiller, 2012). The learner has to take responsibility in the learning process by also reflecting on a series of questions (Where am I headed? Where am I right now? How can I close the gap between where I am and where I want to be?). By so doing, learners develop self-assessment skills which are crucial for life-long learning (Taras, 2010; Leach, 2012). A peer as an agent in the learning process plays a critical role in developing judgment skills through an effective feedback mechanism.

Five Key Strategies of Formative Assessment

i)   Clarifying and sharing learning intentions and criteria for success.

This is the first strategy that involves clarifying, communicating, and understanding learning intentions and criteria for success with students. Teachers are expected to make the lesson objectives or intended outcome clear by ensuring the students understand them clearly. According to Wiliam (2011), teachers, learners, and their peers should jointly break down this strategy into several criteria for success.

ii)   Engineering effective classroom discussions and other learning tasks

The focus of this strategy is on eliciting evidence of achievement which mostly takes the form of questioning. This strategy revolves around the role of a teacher in finding out where the learners are in their learning so that the teacher can know the kind of evidence to collect (Wiliam, 2011).

iii)   Providing feedback that moves learners forward

Research has shown that good feedback is among the most powerful influences on achievement (Hattie & Timperley, 2007; Owen, 2016). The importance of feedback is reflected in the seven principles of good feedback practice in learning proposed by Nicol and MacFarlane-Dickn (2006) as helping to clarify what good performance is; facilitating the development of self-assessment; giving students high-quality information; encouraging teacher and peer

dialogue; encouraging positive motivational beliefs and self-esteem; providing opportunities to close the learning gap and informing teachers about their teaching. Apart from teachers providing feedback, students also engage in self and peer feedback.

iv)   Activating learners as instructional resources for each other

This strategy involves peer assessment whereby learners are involved in collaborative learning. Wiliam (2011) observed that peer assessment which is geared towards improvement rather than evaluation can be more productive than when students interact directly with a teacher. Wiliam further remarked that students benefit more because they work towards a common goal which enhances motivation and that thinking together enhances clarity of concepts. He suggested strategies of peer assessment like peer evaluation of homework using the rubric created by the teacher; student feedback on other students after instruction and peers presenting their reviews to others.

v)   Activating learners as the owners of their learning

Wiliam (2011) suggested that learners owning their learning can only occur within other strategies of formative assessment which involve: Sharing learning goals; promoting the belief that ability is incremental rather than fixed; discouraging students from comparing themselves with others in terms of achievement;   providing feedback that encourages learning and promoting learning autonomy.

Table 1

Features of Formative Assessment

Agent	The direction in which the learner is moving	Current position of the learner	How the learner can get to the desired destination
Teacher	1. Sharing intentions for learning and criteria for success.	2. Classroom discussion	3. Feedback
Peer	Understand and share learning intentions and criteria for success	4. Peer assessment	
Student	Understand intentions of learning and criteria for success	5. Self-assessment	

Adopted from (Wiliam & Thompson, 2008, p. 63)

Aims and Structure of the Empirical Studies

In this series of studies, formative assessment has been conceptualized as a teaching approach with the overall aim of assessing its effectiveness in the teaching and learning process in Kenyan secondary schools. This dissertation thus comprises five related empirical studies. The

first study was a pilot study that examined the suitability of the adapted questionnaire for measuring mathematics teachers' perceptions of formative assessment. The study aimed to find out if the Teacher Assessment for Learning Questionnaire (TAFL-Q) which was developed in the Netherlands by Pat-El et al. (2013) could be applicable in the Kenyan context.

The second study used the validated TAFL-Q to examine the teachers' perceptions and how these perceptions are related to the teachers' metacognitive awareness. A review of the literature revealed that teachers can model students' metacognitive skills (Martinez, 2006; Tanner, 2012). Metacognition is regarded as a very important skill for enhancing 21st-century skills and competencies (Lai & Viering, 2012). In line with the context of the CBC in Kenya, teachers' metacognition is important in developing learners' competencies. The motivation for the second study was thus to find out if Kenyan mathematics teachers' perceptions of formative assessment were in any way related to their perceived metacognition.

The third study was informed by the results of the second study which showed that formative assessment predicted mathematics teachers' levels of metacognitive awareness. The aim was therefore to assess how mathematics teachers' perceived their levels of metacognition and their conception of the different facets of metacognition.

Study four involved the development of a test to measure proportional reasoning skills in mathematics. The test was later used in study five which was an intervention that entailed using formative assessment as an instructional approach to improve students' achievement in mathematics and metacognition. The proportional reasoning test and a metacognitive awareness scale were used to measure the impact of the intervention.

In summary, the studies forming part of this dissertation were carried out in the context of the Kenyan new competence-based curriculum. The overall aim of these studies is to equip teachers and curriculum developers with alternative teaching and learning approaches that can promote the key competencies in mathematics.

Results and Discussions of the Empirical Studies

Study 1: Assessing the Suitability of the Adapted Teacher Assessment for Learning Questionnaire in the Kenyan context

This study sought to examine whether the adapted TAFL-Q can be appropriate in measuring mathematics teachers' perceptions of formative assessment in Kenyan secondary schools. The sample consisted of 180 (138 males) secondary school mathematics teachers. The results of the two-factor model of the TAFL-Q failed to fit well with the Kenyan data (CMIN/DF = 2.643, RMSEA = .096, SRMR = .085, TLI = .653, CFI = .680). It was therefore necessary to carry out an exploratory factor analysis to explore the structural stability of the Kenyan sample.

The results suggested a six-factor structure for 19 out of 28 items based on a principal exploratory factor analysis with varimax rotation. Although no six-factor solution exists in the literature regarding TAFL-Q, the six factors extracted in the present study are underpinned by the formative assessment theoretical framework of Black and Wiliam (2009). These factors were named as Perceived Success Criteria (PSC); Perceived Peer Assessment (PPA); Perceived Self-Assessment (PSA); Perceived Learning Intentions (PLI); Perceived Feedback (PF); and Perceived Classroom Discussion (PCD)

Descriptive statistics indicated that mathematics teachers' level of agreement ranged from low to moderate. The results suggested that teachers had average perceptions of their use of self-assessment, feedback, classroom discussion, peer assessment, and success criteria strategies. They however had a low agreement on the use of learning intentions strategies. Learning intentions and success criteria define where the learner is going (Black & Wiliam, 2009).

Study 2: Formative Assessment as a Predictor of Mathematics Teachers' Levels of Metacognitive Regulation

This study aimed to establish the relationship between mathematics teachers' perceptions of formative assessment and metacognitive regulation using the new structure of the Teacher Assessment for Learning Questionnaire (TAFL-Q) obtained in study one and Metacognitive Regulation Inventory for Teachers (MAIT) which was adopted from Balcikanli (2011).

The new version of the TAFL-Q was subjected to a confirmatory factor analysis using a different sample of 213 mathematics teachers. The new structure resulted in an acceptable model

with good fit indices (CMIN/DF = 2.009, RMSEA = .069, SRMR = .054, TLI = .862, CFI= .889). The confirmatory analysis of the three scales representing metacognitive regulation on the MAIT scale had good fit indices on both the first and the second samples. The fit indices for the second sample were: (CMIN/DF = 2.2411, RMSEA = .082, SRMR = .053, TLI = .917, CFI= .936). There was, therefore, no adjustment of the items on the MAIT scale.

The second part of the study involved assessing the relationship between teachers' perceptions of formative assessment and metacognitive regulation. The results showed a significant positive relationship between most of the factors. For instance, learning intentions (PLI), success criteria (PSC), and peer assessment (PPA) significantly predicted teachers evaluating skills. This implies that mathematics teachers develop evaluation skills when they use formative assessment strategies like sharing learning intentions and success criteria with students and engineering them as instructional resources of one another. Self-assessment, however, had no significant effect on teachers evaluating skills.

Monitoring strategies were significantly predicted by classroom discussion (PCD) and peer assessment (PPA). Through classroom discussion and peer assessment, students can reflect and monitor their learning process. Planning strategies were significantly predicted by learning intentions (PLI), peer assessment (PPA), and success criteria (PSC).

Study 3: In-Service Mathematics Teachers' Conception and Perceptions of Metacognition in their Teaching Experience

This study explored the mathematics teachers' perceptions of their metacognition, the effect of background factors on teachers' metacognition, and teachers' conception of metacognition. Research question one established the extent to which secondary school mathematics teachers in Kenya perceived their level of metacognitive knowledge and skills in teaching mathematics. Descriptive statistics analysis showed that mathematics teachers rated themselves highly regarding their level of metacognitive awareness although their rating for metacognitive knowledge was higher than the rating for metacognitive skills. The analysis thus implies that teachers have positive perceptions of their metacognitive awareness. Descriptive statistics results were also supported by the qualitative analysis of the interview where teachers reported that they were aware of their metacognitive knowledge and skills. The current results are supported by other previous studies (Koc & Kuvac, 2016; Özsoy & Günindi, 2011).

The second research question examined if there was any effect of gender, teaching experience, and level of education on the metacognitive awareness of secondary school mathematics teachers in Kenya. This question was answered by conducting an independent samples t-test and ANOVA statistics. The outcome of the analysis showed a non-significant effect of gender, teaching experience, and level of education on both the metacognitive knowledge and metacognitive skills of the participants. Previous studies although dealing with pre-service teachers also found statistically non-significant gender differences in teachers' metacognitive awareness (Alci & Karatas, 2011; Ekici et al., 2019). These findings show that background factors of gender, experience and level of education have little influence on the in-service teachers' perceptions of metacognition.

The third research question sought to get a deeper understanding of the Kenyan secondary school mathematics teachers' conception of metacognition as reported through interviews. The analysis was based on the two major themes and the subthemes identified during the questionnaire analysis. The first theme, metacognitive knowledge which relates to person, task, and strategy variables (Mahdav, 2014) is divided into declarative knowledge, procedural knowledge, and conditional knowledge. The interview of teachers regarding their metacognitive knowledge revealed that teachers made use of their metacognitive knowledge. For instance, they were able to identify their strengths and weaknesses (declarative knowledge); used varied teaching approaches (procedural knowledge); and made good use of their strengths and weaknesses (conditional knowledge).

The second theme analyzed teachers' metacognitive skills which encompass planning, monitoring, and evaluation. Analysis of teachers' metacognitive skills revealed that teachers generally had an understanding of the skills involved in the regulation of cognition but rarely put them to use. These results show that more effort is needed for teachers to translate their awareness of metacognitive regulation to their teaching.

Study 4: Proportional Reasoning in Mathematics: Construction and Validation of a Test to Measure Students' Proportional Reasoning on Rates, Ratios, and Proportions

The results for this study are presented based on the three analyses that were done: reliability, item difficulty, and item discrimination. Cronbach's alpha was used to determine the internal consistency of the test. The overall test reliability for the 10 items was .83 with a mean

of 1.30 and a standard deviation of 0.38 which was within the acceptable range (Cohen et al., 2007). All items had item-total correlation (ITC) values ranging from .32 to .67 indicating that the items fitted well to the whole test.

Item difficulty is a measure of the percentage of students answering a test item correctly and it helps in determining how easy the item is (Hopkins, 1998). Item difficulty index (p-value) can also be used to determine the validity of test items. The difficulty index ranges from .0 to 1.0 where the higher the p-values the greater the percentage of students answering the item correctly. The difficulty index of the test items ranged from .39 to .50 which implied moderately difficult items (Table 27).

The item discrimination index (DI) was used to measure each test item to distinguish the performance of students. This was done by calculating the difference in the percentage of high achieving students who got an item correct and the percentage of low achieving students who got the item correct. The discrimination index ranges from -1 to +1 where positive numbers above 0.2 show that an item is positively discriminating. The item DI ranged from .17 to .44.

Study 5: Impact of Formative Assessment Instructional Approach on Students' Mathematics Achievement and their Metacognitive Awareness

In this research, the influence of formative assessment on students' mathematics achievement and their metacognitive awareness was explored. The participants included 164 grade 11 students (84 male) and four teachers from four low achieving rural secondary schools in Kenya. Four research questions guided the study. Research question one sought to establish if there was a significant difference in the posttest scores between intervention and control groups after the treatment. Results exhibited a significant difference between the posttest scores of the two groups with a medium effect size ($\eta2 = .38$) after controlling for the pretest scores. This implies that students who were exposed to formative assessment strategies performed better than those who were taught conventionally.

The second research question was concerned with whether gender influenced mathematics achievement scores after the intervention and whether a significant interaction between gender and the type of teaching approach and the posttest scores were exhibited. The results revealed that after controlling for pretest scores, gender had no influence on the posttest scores. There was also no evident interplay between gender and the type of teaching approaches, and the posttest scores. The results suggest that formative assessment had a similar influence on

the learning of both male and female students. Therefore, one may infer that the improvement in achievement in the intervention group was associated with the formative assessment instructional approach and gender had no influence on this approach.

The third research question focused on whether the teaching approach had an influence on the students' posttest scores on metacognitive awareness. The results revealed that students who received instruction using formative assessment had a higher metacognitive rating than those who were taught using conventional methods. The items on Junior Metacognitive Awareness Inventory (Jr. MAI) assessed students' metacognitive awareness, which comprised knowledge and skills dimensions. Knowledge of cognition involves awareness of and knowledge about one's cognition (Harris et al., 2010). On the other hand, metacognitive skills involve planning, monitoring, and evaluating learning processes (Veenman & Beishuizen, 2004).

The fourth research question was concerned with the influence of gender on metacognitive awareness posttest scores and whether there was an interaction between gender and the type of teaching approach and metacognitive awareness posttest scores. The results revealed that gender had an insignificant influence on metacognitive awareness posttest scores. Furthermore, no significant interaction between gender and teaching approach, and the posttest scores were found. Although research on gender and students' metacognition has been less extensively studied, some studies have suggested that students' metacognition is gender independent (Al Shabibi & Alkharusi, 2018; Siswati & Corebima, 2017).

Practical recommendations

This research recommends that the training of pre-service teachers on formative assessment should be more emphasized in the teacher training colleges. Currently, formative assessment is generally taught as an aspect of educational assessment but more emphasis should be placed on the specific strategies involved in formative assessment. For the in-service teachers, we recommend that teachers should be involved in designing the programmes related to formative assessment so that they can actively take part in the implementation process. Most of the professional development programmes that have taken place in Kenya have been centralized and only involve a few stakeholders.

From the interview analysis in study three, teachers seemed to have little understanding of the concept of metacognition. In this line, we recommend the introduction of metacognition at

the pre-service teacher training colleges so that the prospective teachers will be able to model the same to their students when they start teaching. Metacognition training can also be incorporated into the already ongoing in-service teacher training program on the Strengthening of Mathematics and Science in Secondary Education (SMASSE).

Limitations

There were some limitations that were encountered in some studies. The second phase of research was an intervention that coincided with the COVID 19 pandemic in 2020. As a result of this, the duration of the intervention study was shortened. We had planned to carry out a formative assessment intervention for eight weeks but due to learning interruptions, we only did it for four weeks. Due to this limitation, the results of the intervention study cannot be generalized to a larger population. It was also not possible to involve a large sample size and do classroom observations due to the COVID 19 related restrictions.

Summary

This research project was conducted between 2019 and 2021. The research was done in the context of Kenyan secondary schools and it involved mathematics teachers and grade 11 students as the participants. The focus was on formative assessment conceptualized as an instructional approach in the teaching and learning process. This dissertation, which comprises five chapters, represents the original work stemming from dedication and hard work. In chapter one, the introduction to the study is given. The focus is on the study context, problem statement, significance, and the structure of the dissertation. The results of the literature review on the themes related to the study are presented in chapter two whereas chapter three presents the aims, research questions, hypotheses, and methodology of the empirical studies.

Chapter four presents a series of five empirical studies in which 15 questions and 17 hypotheses are addressed. Study one assessed the suitability of the adapted teacher assessment for learning questionnaire in the Kenyan context. Study two examined the relationship between formative assessment and mathematics teachers' metacognitive regulation. Study three assessed teachers' perceptions and conception of metacognition. In study four, a test to measure students' proportional reasoning skills in mathematics was constructed and validated. Study five examined the impact of formative assessment on students' achievement in mathematics and their metacognitive awareness.

These studies though related are presented as separate journal articles. The results, discussions, conclusions, limitations, and implications are thus given based on individual studies. Chapter five presents a general discussion of the results by addressing each research question and the corresponding hypothesis. General and practical recommendations are also given. Since no such research has been conducted in Kenya before, the present research forms a basis for further studies on formative assessment conceptualized as an instructional approach in the teaching and learning process. The current research adds knowledge to the limited empirical evidence regarding the impact of formative assessment conceptualized as an instructional approach on students' academic achievement and metacognition in mathematics.

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