METACOGNITIVE TRANSFERENCE: WHAT PORTFOLIOS TELL US ABOUT CONTEXTUALIZED MATHEMATICS

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ABSTRACT
Recognising the value of ethnomathematics is an important aspect of education worldwide. While the value of IK in education has been recognised, this recognition is yet to translate into practical curriculum processes. It is not clear how metacognition can drive the transference of knowledge and skills into the classroom while, at the same time, contextualising mathematics. One approach is to introduce teachers to viable ways of contextualising mathematics, through ethnomathematics, and equipping them with metacognitive strategies (e.g. planning, monitoring and evaluating) to do so. Metacognitive transference and its relationship with ethnomathematics is the subject of this paper as it reports on what the portfolios tell us about contextualising mathematics and how metacognition transference takes place. An interpretivist-qualitative approach as research design was employed. Data collection instruments included lesson plans, reflections and open-ended questions. Content analysis, based on the conceptual-theoretical framework of this study, ensured validity of the findings which revealed that, three tiers (levels) that portray the interrelated nature of teachers' cognition, intra- and interpersonal competencies could enhance their PCK.

Keywords: Metacognition, transfer, PCK, Ethnomathematics, cognitive, intra- and interpersonal competencies

1. INTRODUCTION

The twenty-first century has brought with it a number of educational challenges for teachers and learners who face several constraints that affect good performance in the STEM related subjects (Centre for Development and Enterprise (CDE), 2014). One of the factors listed in the CDE-report emphasises teachers' underdeveloped pedagogical content knowledge (PCK) as one of the major reasons for underperformance in the science arena. Nationally, the Department of Basic Education in South Africa (DBE & DHET, 2011) confirms that part of the challenge is the shortage of teachers who are qualified and competent to teach mathematics. With the recent emphasis to include indigenous knowledge (IK) in the mathematics curriculum (DBE, 2012), the need for professional advocacy increases.

Concepts relating to 21st century competencies, contextualising mathematics and transference were aligned against the theoretical framework of metacognition and pedagogical content knowledge aimed to explain how teachers transferred what they had learned in the Short Learning programme Ethnomathematics (SLP) into their classrooms.

2.CONCEPTUAL FRAMEWORK

The National Research Council (2012) proposes that success in work and life in the 21st century is associated with competencies in three domains: cognitive, intra-, and interpersonal. A competency involves content knowledge in a domain as well as procedural knowledge of how, why, and when to apply this knowledge (the ability to meet complex demands) and to transfer what was learned in one context to new contexts. Cognitive competencies involves abilities, such as reasoning, problem solving, and memory of facts and procedures (Bloom 1956). Intrapersonal competencies involves the affective domain: emotions, attitudes, beliefs and feelings and includes a process called

'metacognition' the ability to set and achieve one's goals and to reflect on one's teaching and adjust teaching strategies accordingly (Hoyle & Davisson, 2011). Interpersonal competencies (social) are those used to communicate information to others and to interpret others' verbal and nonverbal communication and respond appropriately (Bedwell, Fiore, & Salas 2011). Abilities and beliefs underlying metacognitive awareness (intrapersonal) are developed through social processes (Newman, 2008).

1.1. Contextualising mathematics through the infusion of IK

Throughout history, different cultures developed mathematics in various ways to meet the needs of their people. Current trends in education include the investigation of mathematical ideas and practices that occur outside the school in order to help teachers pedagogically through contextualised activities (Rosa & Orey, 2013). One such an example is IK the local knowledge that is unique to a given culture or society that evolves and changes as it develops, influenced by interactions with other knowledge systems (Izmirli 2011). Ethnomathematical perspectives imply that ideas of different cultural groups become part of learning experiences in various ways (Dickenson-Jones 2008).

Western mathematical ideas are often taught and learnt in an abstract context. When these ideas are deliberately contextualised in IK as real life experiences, it provides a sense of purpose and relevance for learning maths in terms of the development of western mathematical understanding (Ainley, Pratt & Hansel, 2006). This process of mathematising can then be considered as the expression of mathematical ideas emerged in real contextual problems, and the solving of these mathematical problems would require not only knowledge and skills, but also the embedded cultural experiences, values and attitudes (Gavarette, 2015).

1.2. Theoretical Orientation and the emergence of tiers

The concepts outlined above conform to some theoretical alignment as they require an extent to which the teaching-learning experience is comprehended, an awareness of the emerging perceptions from this experience and a collective understanding of how these perceptions come together and shape future experiences.

1.3.The theory of metacognition

Metacognition is known for two facets: metacognitive knowledge (of self, task & strategies) (Flavell, 1979) and metacognitive regulation (planning, monitoring and evaluation) (Little & McDaniel, 2015). The regulatory facets serve as the mediating processes through which the metacognitive knowledge facets are brought to mind. This suggests that one's knowing of mathematics, is not the only requirement for a quality teaching-learning experience, but also knowing how to plan lessons, how to monitor progress and knowing how to evaluate the success of the teaching-learning experience. These metacognitive pre-requisites are referred to as the capacity needed to improve teaching quality. A teacher could recollect a strategy to teach a mathematical idea (plan), but realise that he/she cannot apply the idea in an IK context (monitor & self-knowledge), and might overlook that cultural needs and diversity in the classroom (knowledge of others and task).

The capacity to interlink the cognitive, intrapersonal and interpersonal competencies related to the teaching enables the teacher to practice metacognition and guides the PCK related to the content and context of teaching. Such experiences seem to develop across different but inseparable (theoretical) tiers. Each tier represents one or more of the metacognitive aspects at a particular reflective instance of the lesson. Careful consideration of what metacognition and PCK entail, enables an approach to understand: 'How mathematics teachers, who attend a SLP on the affordances of IK for the mathematics classroom, transfer mathematical ideas from one context to another'.

In light of Brinck and Liljenfors's (2013) theoretical perspective on metacognition, Markova and Legerstee (2013) argue that metacognition emphasises social and cognitive meta-representations that refers to cognitive, intra- and interpersonal domains as 21st century competencies and the affect directed at the content (NRC, 2012). Tying 21st century competencies, contextualised mathematics and transference to quality teaching-learning experiences to implicit, perceptual and meta-representational levels (Brinck & Liljenfors's 2013), as theory of metacognition, three theoretical tiers emerge. The tiers include: (Tier 1) instigations of a quality teaching-learning experience; (Tier 2) emerging perceptions on the lesson plan in practice as experience and (Tier 3) as the totality and overall reflection on of the perceptions held on mathematics and IK as integrated into the lesson.

1.4.Pedagogical content knowledge as theory

The teaching profession requires the capacity to make sound pedagogical decisions that are systematically infused from the interaction between the content and the context. Decisions about what teaching strategies to use and how to manage or structure the lesson typically manifests as visible routines in the classroom and can be regarded as the essence of the teaching practice itself (Rusznyak & Walton, 2011). These decisions require coherent planning of the kind of experiences that the teacher wants to accumulate from the teaching strategies used. These understandings (of what, who and how to teach) promote the pedagogical knowledge as well as the content knowledge of the teacher and assist the development of 21st century competencies.

Cognitive competence and the mathematics lesson plan

It is (often) because of a lack of these *competencies* that teachers present a lesson in an almost mechanical fashion. When the fusion between content and pedagogy did not take place, the quality of the learning experience is at risk as the complexities that reveal the inner working of the mind (that is metacognitive) become overlooked. As such, blending the content knowledge, knowledge of learners and their context and pedagogical knowledge into the learning experience is not only a powerful background for teaching, but also constructs PCK of the teacher (Rusznyak & Walton, 2011). As a result, the teacher's knowledge impacts on the quality of the proposed classroom practice (lesson plan) and (through reflection) creates opportunities for pedagogical reasoning through reflection. Reflection is often difficult to articulate if the language of thinking is not developed. A reflective narrative of the lesson plan, in this sense, can extend the management of the cognitive ideas to afford a more intrapersonal competence.

Intrapersonal competence and the ideas based on experience

While building pedagogical content knowledge, the teacher's knowledge informs practice and creates a shift in thinking from a mere "doing" teaching to a more pedagogical reasoning about teaching (Rusznyak & Walton, 2011). This shift towards a pedagogical reasoned approach helps the teacher to cope with the cognitive demands of planning and presenting the lesson. As the teacher reflects critically, the practice of the lesson offers more to the development of professional knowledge for teaching and transforms the lesson plan into a systematic presentation of the teaching-learning experience. The perceived lesson outline promotes PCK, enables the use of additional skills and knowledge to transfer these reasoning into the classroom. Adequate content knowledge, in this sense serves as a catalyst for the construction of PCK and gives, not only, direction for future classroom experiences but also helps in identifying gaps in ones PCK.

Interpersonal competence and the ideas of others

Expressing interpersonal competence through critical reflection on the lesson plan creates an opportunity for others to engage in the discourse about the lesson, and creates a framework for understanding teaching expertise. As this involves effective communication, professional knowledge becomes supported by the cognitive skills used to process and interpret the ideas on which the lesson

plan is based, as well as the views that emerge from the teaching experience (Bedwell, Fiore, and Salas, 2011).

Based on our understanding of the above, Figure 1 was developed to illustrate the relationship between the conceptual and theoretical framework of this study. In particular, it is conceptualised that the triadic process of metacognitive transference occurs across three tiers in which cognitive, intra- and interpersonal competences emerge.

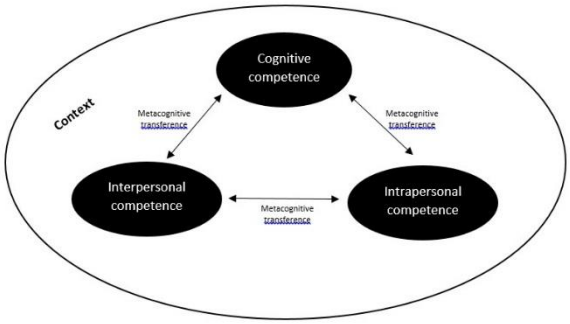

Figure 1. Conceptual-theoretical framework

Theoretically, Tier 1 provides the space for teachers' to describe the intended classroom procedures and reflects the role cognition plays in the construction of pedagogical content knowledge. Tier 2 serves as the platform (through reflective narrative) on which the lesson plan is reflected upon as it is experienced and Tier 3 provides the overall view on of the perceptions and ideas that unfolded form the lesson plan experience.

One such an attempt is reported on in this paper with an emphasis on the nature of the (intra) processes involved when teachers transfer knowledge about the content and the procedures of how, why and when they apply this knowledge. This form of metacognitive competency was the initial aim of a Short Learning Programme for mathematics educators on transferring ethnomathematics content into their classrooms. Specifically, the study aimed to answer the question: How do mathematics teachers, who attend a SLP on the affordances of IK for the mathematics classroom, transfer mathematical ideas from one context to another? To answer this question, the study followed an interpretivist-qualitative approach as research design.

3. RESEARCH METHODOLOGY

The content of the SLP included different ways different cultures represented multiplication; contextualising mathematics topics in indigenous games (e.g., Ncuva and Morabaraba) and -music; mathematizing the familiar concepts contextualised in IK to be able to solve problems; and metacognition.

3.1 Population and sampling:

Teachers were invited to voluntarily participate in the SLP workshop (both in Limpopo Province (N= 69) and North-West Province (N= 19)) during the 2016 June/July school holidays. Teachers also had the choice to submit a portfolio after attending the SLP workshop. Only 20 teachers submitted portfolios (Limpopo n = 19; NorthWest n = 1).

3.2 Data collection instrument

The evidence-based portfolio required of mathematics teachers (i) to develop three lesson plans (a lesson plan template was provided) where they have contextualised mathematics topics in indigenous games, -music, or -art; (ii) to write a narrative in which they reflect on their own PCK and lessons; and

(iii) to answer two open-ended questions regarding their views on using indigenous games in their mathematics lessons and their interpretation of the relatedness of music and mathematics.

3.3 Data analysis

Content analysis based on the conceptual-theoretical framework of this study has led to the development of a multi-dimensional rubric for assessing the contextualisation of mathematical ideas and metacognitive reflection for enhancement of PCK.

Table 1 Data analysis framework of the three tiers relating to the conceptual-theoretical framework

Tier 1	Tier 2	Tier 3
-Nature of mathematical tasks -Mathematical tools to support learning -student strategies -appropriate assessment method -organisation of lesson -detail of planned lesson	-assessment measure appropriate to task -What should change next time? -What went well in this lesson? -What problems were experienced? -What learned from this experience will help in the future?	-Communication of views regarding the usefulness of IK in the teaching-learning of mathematics -Interpretation of the relatedness between mathematics and context

3.4 Validity

Data analysis was based on conceptual-theoretical framework to ensure the validity of findings.

4 FINDINGS

4.1. Tier 1: Cognitive competence in the Lesson plan as a tool to instigate a quality teaching-learning experience

The items measured in the lesson plan (Table 1) focused primarily on cognitive competencies outlined by the conceptual framework of this study and involved technical matters such as completing the lesson plan correctly by stating what topic will be covered, what the aims and objectives are and how the teaching-learning experience unfold throughout the lesson plan's phases. The findings regarding the cognitive competencies can be outlined across three clusters, each representing a deeper level of cognitive competencies.

In the first cluster the lesson plan was only completed in part with little to no details offered as to what the different items involve. In the second cluster, participants performed better in the technical matters of the lesson plan, indicating stronger cognitive competence in the lesson plan items by adding details to the implication of items of the lesson plan in practice. They stated the topic and aims very clearly and provide a brief outline of how they cater for learners to engage with the new content, and how they plan to assess whether the outcomes have been reached or not. Similarly the third cluster expressed detail regarding the lesson plan outline and communicated their ideas about the different lesson plan phases more clearly. They showed a strong cognitive competence in their reflection on lesson plan's effectiveness. Conceptually the emerging characteristics of participants in clusters 1, 2 and 3 emphasise the important role that cognitive competence plays in the intrapersonal and interpersonal competence.

4.2. Findings Tier 2: Reflective narratives as a tool to capture emerging perceptions on the lesson plan as experience

The reflective narratives (Tier 2) were used as a tool to capture emerging perceptions on the lesson plan as experience. Mainly, this was done to elicit the responses regarding the intrapersonal

competencies of the participants. All participants commented on what they have learned from this experience with the lesson:

…I need to upgrade myself in terms of music and mathematics' connection…I will try to be more creative…I will give myself more time to prepare…

Participants from **Cluster 1** did not reflect on how their learners did. But did indicate what they would change next time:

I intend to discuss the lesson plan with colleagues…next time I will spend less time on explanations…

Participants in **Cluster 2** mainly focused their reflections on how their learners did and what the lesson plan as experience offered them.

Learners could see, hold and cut various shapes… they showed that they understand the lesson…they enjoyed playing the [IK] game …

It seemed that these participants did not reflect on what problems were experienced during the lesson, instead there was a strong emphasis on the learners' experience of the lesson. Participants in **Cluster 3** commented on the active participation of learners during the lesson plan and the close link that should be between the IK activities and the learning activities:

Learners should not only play Morabaraba without responding to learning activities…

And commented on their ideas for future lessons:

I will design a lesson that will help them understand mathematical language…set realistic goals at the end of the quarter …to vary teaching strategies.

4.3. Findings Tier 3: Completed questionnaire as a meta-representation of the perceptions held on mathematics and IK

Five main themes submerged from participants' responses regarding their views about mathematics and IK and serve as meta-representations of their perceptions about mathematics, and IK. Views regarding mathematics are expressed with a strong cognitive competence where participants claim IK in the classroom can enhance the understanding of mathematical concepts such as geometry, number patterns, proportion, ratios, measurement, and fractions. The second prominent theme involves the affective domain as participants claim that mathematics has to be interesting and fun. This will ensure active participation where learners engage in critical thinking and interact as they learn through play. As such, cooperative learning of mathematics can create a change in mindset, as one participant claims and, according to the teachers, a love for mathematics will develop. The third theme of metacognitive knowledge pertain, to the awareness of the person, task and strategy knowledge. That is, participants acknowledge that they believe mathematics is everywhere whereby they perceive their awareness of the world around them. They mention "abstract thinking, strategic thinking and critical thinking" as important ways of knowing and doing mathematics. The fourth theme of attributes focus on the limitations that participants had experienced such as time constraints, workload, or their lack of understanding or having knowledge of music and its western notations. The fifth theme involved the relationship between mathematics and music. Participants gave numerous examples of how they can contextualize mathematics by means of music. Some examples include using musical intervals to illustrate sound waves when teaching graphs, using the rhythms for number sequences, patterns and counting. One participant, for instance, explained that "*I got lost in context of piano music that was used".*

5. DISCUSSION

Tier 1: Cognitive competence seem to relate closely to the content and outline of the lesson plan as well as the content and overall structure of the CAPS. Participants who could not provide details about the sequence of events in the lesson plan (cluster 1) seem to lack the relevant knowledge and understanding of the CAPS. Those who did well in the lesson plan (cluster 3) showed a deeper understanding of the relatedness between the mathematics topics on which the lesson plan was based and the context. Overall, participants struggled to infuse contextual elements (integration of IK with

the CAPS) in their lesson plans. One could suspect that participants in cluster 1 were under-qualified to teach mathematics as they had little cognitive competence regarding the lesson plan outline which also hints on less experience in teaching mathematics, than those participants in cluster 3. Participants in cluster 3 seemed to have received training as to how to plan a lesson plan and how to communicate their ideas about the lesson plan, typically what one can expect from teachers who are qualified for teaching mathematics. It seemed that all participants struggled to reflect on their lessons and had difficulty to express and communicate their ideas clearly. Contextualising of mathematics (lesson plan) seemed to be an overall challenge that participants experienced. If therefore seemed that participants could not transfer knowledge (of CAPS) and skills (of infusing IK) that they have not yet learned.

Tier 2: We notice there are differences between the scope and depth of participants' reflections across the four clusters. Overall, none of the participants reflected on their method of assessment, indicating a possible lack in metacognitive monitoring and evaluation of their lessons.

Tier 3: Open ended questionnaires focused on participants' views on the usefulness of IK, relatedness between mathematics and the context (e.g. music). The themes include: (1) views regarding mathematics, (2) affect, (3) metacognitive knowledge, (4) attributes of teaching success and (5) views regarding the relationship between music and mathematics. It is important that there must be alignment between what IK is and what western knowledge is in the curriculum.

6. CONCLUSION AND RECOMMENDATIONS

In this study we attempted to explain how metacognitive transference takes place and how it relates with ethnomathematics. We learned that metacognition is important to be facilitated as this capacity unfolds across the lesson planning, reflection on the lesson and views about mathematics and its relatedness to context. The awareness of the three emerging tiers can enhance not only the metacognitive awareness, but also the PCK needed to teach mathematics. What is needed now is ongoing investigation into the role and nature of metacognitive transference and its association with views about mathematics and IK, the affective domain, metacognitive awareness and other relevant attributes to the teaching-learning of mathematics.

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