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The missing link: how ICTs contribute to retention of mathematical concepts. A conceptual study

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ABSTRACT

Numerous reports, such as the Trends in International Mathematics and Science Study (TIMSS) reports have shown that South African learners have been struggling in mathematics education. Perkins (1991) listed the three goals of (mathematics) education as retention, understanding and application. Education, which is used interchangeably with learning in this research, refers to the process whereby learners understand, retain and apply mathematical concepts. Therefore, poor achievement in mathematics education is in essence a failure to understand, retain and apply concepts. Retention, a core category studied in this research, is considered not only an educational goal but also important in making further learning in mathematics, possible.

I decided to focus on retention, even though it is just one of the three goals of education because my observations over many years of teaching mathematics, confirm its centrality in the subject. It has also been quite evident from this research, that learners often struggle with concepts, even ones they initially demonstrated an understanding in. It was noted that generally, learners tend to do very well in assessments administered soon after a lesson but struggle with the same concepts if they are asked to demonstrate an understanding later in a delayed assessment, a phenomenon that was also observed by Kang (2016).

While much research has been done that generally points to the inadequate pedagogical and content knowledge of teachers, especially in South Africa (Venkat & Spaull, 2015; Bowie, Venkat & Askew, 2019; Bansilal, 2015; Taylor, 2019), this research's view is that delayed assessments are responsible for students' low performance in the subject. Comparing assessments administered close to when the concept was taught and end of term and year exams confirm the negative impact of delayed tests on mathematics performance. This confirms the importance of retention, and that although many learners understand mathematical concepts, they fail to retain that understanding for a long time which in turn hampers further learning (Karagiorgi & Symeou, 2005; Wilson, 2009). Quite often, the failure to retain concepts is often confused with a failure to understand concepts, especially in delayed assessments. Although these two goals are related, they need to be viewed as separate but connected entities. Retention of concepts, which is defined collectively by its indicators discussed in the research, plays an integral role in supporting mathematics, which in the present research is hierarchical, sequential and connected (Wilson, 2009). In turn, a number of authorities have flagged Information and Communication Technologies (ICTs) as affording practices that enhance retention (Ferriman, 2014).

So, although this conceptual paper will study the importance of this goal in mathematics education, it will also focus on how ICTs promote retention with the intention of constructing a pedagogical framework guiding ICT integration in the subject. This focus gets support from Kennewell (2006) who argued that (technological tools) will not act independently of pedagogical settings in which they are used and that an evaluation of the impact of ICT on teaching and learning, requires an "…accompanying detailed analysis of the complete pedagogical setting" (p. 102).

ICT affordances must, therefore, be viewed in terms of their impact on indicators of retention within specified pedagogical contexts. Indicators of retention are practices and behaviours that enhance retention. Certain technological tools and certain uses of these tools and software tend to predispose some of these technologies to an advantage over others in enhancing and supporting retention of mathematical concepts.

A conceptual study was used in this research because it allowed the research to reinterpret existing data to bridge the gap between existing major concepts, categories, theories and models in order to offer new insights and support inferences from existing literature and documents that broaden the current pedagogical thinking on ICT integrated mathematics learning (Gilson & Goldberg, 2015). Conceptual papers, by their very nature do not follow the status quo (Gilson & Goldberg, 2015), as will be seen in this research, usually because their thrust is to solve practical problems through the delineation of constructs, premises, assertions and reinterpretations from a variety of theories and data that converge around the topic. The simplicity in which this research is presented is deliberate. It is meant to make its adoption easier in order to improve mathematics performance.

A grounded theory methodology was used to study the following four main categories, with ICT and retention being the core themes of this research: ICT affordances; the nature of mathematics; the function of retention in mathematics; and the enabling pedagogical framework that leverages the potential of ICTs to support the retention of concepts. Initially, all the above four above categories were studied separately, but thereafter, were systematised into a pedagogical framework. During data collection and analysis, the silo approach of studying the categories was not always sharply defined and linear, as evidenced by the many back and forth connections with other categories that formed the basis of discussions where clear links existed and permitted it. The research started with skeletal low level and emergent categories on the nature of mathematics and the category of retention. These emerged from the initial engagement with literature in the literature review section. Thereafter, a semi-structured discussion strategy on sources was adopted to approach the data

collection with these skeletal low level and emergent categories being utilised as 'lenses' to guide the initial stages of collecting data and analysis. This process culminated in the categories being further refined and developed and prepared them to build inter-category connections necessary to construct a suggested framework.

The nature of the research required me to make interpretations and reinterpretations and necessitated the extensive use of metaphors. The metaphors of building and blocks were used not only to show a hierarchy, but also the sequence and connections implied in the nature of mathematics taught in Finland, and the official books and curricular from South Africa and Zimbabwe. Other metaphors used relate to tentacles and hooks that all signify the importance of connections and in certain instances, highlight conceptual disconnections in learners' conceptual understandings as a result of pedagogies that obliviate learners' current and previous learning experiences and skills. While initially I had hoped to confirm that ICT tools are mainly learning tools, a study of data sources indicated that their abilities to keep records and provide feedback at the click of a finger makes them invaluable teaching tools that support retention as well.

Among others, the recommendation that stands out in this research is that the nature of mathematics demands individualised attention and that teaching and learning should be differentiated based on learners' prior available (retained) understandings. Retention itself is an individualised process that depends on and build upon each learner's previously retained concepts. The multiple processes required to cater for different learning styles and paces in order to democratise mathematics learning requires the careful use of ICT tools, whose potential affordances allow them to function as an assistant teacher and make processes that would ordinarily be impossible, possible. ICT tools effectively used while catering for differentiated learning becomes invaluable tools of inclusion, especially of learners who were not previously catered for in a classroom where the teacher focuses on the average, and not those who are considered outlier learners.

The research concludes by putting the various elements of low level and emergent categories together to construct a pedagogical framework that guides teachers on the use of ICTs to enhance the retention of mathematical concepts. This new framework, which is currently not in existence, constitutes what has been referred to as the 'missing link' of the research.