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Cognitive Profile in Learning Mathematics With Open Calculation Based on Numbers Algorithm

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ABSTRACT

The open calculation based on numbers (ABN) is an innovative mathematics teaching-learning methodology used with a huge number of school children. The aim of this work was to study the cognitive profiles associated to ABN method, compared to those following a closed procedure traditional methods based on ciphers (CBC). A total of 128 first-year students of primary school were evaluated on cognitive and mathematical performance. An experimental group (n = 74) and a control group (n = 54) were formed. The experimental group learned mathematic using the ABN methodology and the control group used a CBC methodology. The cognitive profile of the experimental group emphasized the significance of visuospatial working memory in mathematical performance. Students trained with ABN method seem to operate better with working memory, applying mentally visuospatial representations.

Perfil cognitivo asociado al aprendizaje matemático con el método algoritmo abierto basado en números

Palabras clave:
Cognición matemática
Memoria de trabajo
Método ABN
Método CBC

RESUMEN

En los últimos años un procedimiento metodológico innovador ha permitido plantear el aprendizaje de las matemáticas a partir de algoritmos abiertos basados en números (ABN) en una amplia población escolar. El objetivo de este trabajo ha sido estudiar los perfiles cognitivos asociados al método ABN, comparándolo con el alumnado que siguen un procedimiento de algoritmos cerrados basado en cifras (CBC). Se han evaluado componentes cognitivos y matemáticos a un total de 128 estudiantes de primer curso de educación primaria. Se distribuyen en dos grupos —experimental (n = 74) y control (n = 54)— que siguen un aprendizaje matemático con metodología ABN y CBC, respectivamente. El perfil cognitivo del grupo experimental enfatiza la importancia de la memoria de trabajo visuoespacial en el desempeño matemático. El alumnado instruido con el método ABN parece operar mejor con la memoria de trabajo, aplicando mentalmente las representaciones visuoespaciales en las que han sido entrenados.

Introduction

The current position with respect to math performance has focused the researchers' attention for the study of learning difficulties in mathematics (Butterworth, Varma, & Laurillard, 2011). New intervention methods for improvement have been proposed (Aragón, Aguilar, Navarro, & Araujo, 2015; Martínez-Montero, & Sánchez, 2013). When we refer students who present difficulties in learning mathematics, mean that they are not able to appropriately deal when solving problems or calculations and his or her math skills do not match those that show other students of the same age (Fletcher, Lyon, Fuchs, & Barnes, 2007; Fuchs et al., 2008). A recent study confirmed that learning difficulties arise before formal education (Aunio, Heiskari, Van Luit, & Vuorio, 2015). The science education report by the European Commission (European Commission, 2015) warns of declining interest in the study of science and math in primary and secondary school and the need to increase demand

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for these studies on higher-level education, given the progress of the knowledge society.

For a long time in the school context, calculation learning and practice has been mechanically teach and supported in a traditional closed algorithms based on ciphers methodology (CBC). This practice should raise the development of lower order cognitive skills.

Some strong criticisms with CBC teaching method for basic math facts have been described (Kamii & Rummelsburg, 2008). It could undermine a significant student learning. This argument is based on the rejection of repetition and passive learning promoted by CBC learning. Students could not understand the underlying operations principles. Additionally, there is some empirical evidence that CBC methodology can be disadvantageous to learning mathematics. Martínez-Montero (2011) points out some: impoverishment of strategies and spontaneous student's methods to deal with tasks of non-routine calculation; nesting serious conceptual errors in calculation details hidden by the structure of the classical algorithms, and finally, the lack of significance of the quantities expressed in ciphers in a broader range than expected age.

Similarly, Torbeyns, Verschaffel, and Ghesquiere (2005) suggest that mathematics learning must go "beyond an expert routine; this is the ability to quickly and accurately solve mathematical tasks through standardized strategies" (p. 1). These authors state that students must develop expertise in calculating in a flexible way, creating and using significant strategies such as, for example, compensation strategies. They are essential for basic numerical facts; moreover, the development of self-confidence in their own strategies.

There are several alternative procedures to address and solve mathematical learning problems arising from CBC methodology. One is called open algorithm based on numbers (ABN) teaching method. ABN is based on methodological principles developed by Martínez-Montero (2011), method's designer. The name ABN describes the main characteristics of open algorithms. These are: (a) open algorithms (A). There is no single way to solve them; each student can do this differently, depending on their rate of learning, math proficiency and calculation strategies. This new methodology allows each student to solve operations according to their capacity. This means that an effective motivation improvement and a satisfactory change in the attitude towards mathematics can be reached (Martínez-Montero, 2010; Martínez-Montero & Sánchez, 2011); (b) based on numbers (BN). It means that the algorithm always works with numbers. In any cases the complete numbers are combined with all its meaning, unlike traditional algorithms (CBC) that are based on ciphers, and it does not work with total quantities; (c) the ABN method is transparent. When children are solving any math task, no calculations or intermediate processes are hidden. The ABN method main target is that students understand the basic process of what they are doing all the time, and (d) math facts could be solved from left to right side or, if necessary, from right to left. The directions that students take in solving calculation tasks will be a function on their own learning style and rhythm: his or her own technique in applying mental calculation strategies in written format. The most commonly strategies used are decomposition, rounding and compensation.

The ABN method has precedents some educational proposals launched in the Netherlands to renew the mathematics teaching and learning in general and particularly teaching methodology for calculation. This was called "realistic mathematics." This is oriented to development mathematical competence and fostering mathematical reasoning through manipulative and stimulating instruments for students in order to increase motivation and attention (Van den Heuvel-Panhuizen, 2000). So far three paths teaching and learning have been implemented: first, for calculating with whole numbers in the lower grades of primary school (Treffers, Van den Heuvel-Panhuizen, & Buys, 1999), second for primary school higher grades (Van den Heuvel-Panhuizen, 2001), and third for measurement and geometry in primary school early grades (Van den Heuvel-Panhuizen & Buys, 2005). These paths have been successful and have led to a thorough review of our thinking in mathematics teaching (Van den Heuvel-Panhuizen, 2008).

Implementation of ABN procedure begins in the academic course of 2008/2009 in a group of first grade of primary school in a public school at Cadiz (Spain). One year later, ABN extends in four more schools in the same province with approximate 125 students first graders. During the 2011 to 2012 different nationwide schools started implementing ABN method, distributed by more than 10 Spanish autonomous communities. Throughout 2013 keep growing the Spanish public schools using this method, and starting from the first year of preprimary education. In addition, ABN begins to expand internationally in other countries such as Mexico, Argentina or Chile. But there are still no published results on these experiences. According to data provided by Cantos (2016); currently between 6000 and 7000 classrooms follow the ABN methodology, representing an approximate total number of 200,000 students learning math with ABN.

Parallel to this procedure dissemination, some studies on ABN methodology have been developed for analyzing and comparing reached outcomes comparing to the CBC methodology. Results suggest a significant improvement for students instructed by ABN (Martínez-Montero, 2011).

Moreover, Bracho, Adamuz, Gallego and Jiménez (2014) studied the development of the number sense reached at the end of the primary school second grade after using ABN methodology, paying special attention to the results obtained by students with different learning proficiency. The data show significant differences between mathematical competences achieved in the group using the methodology ABN compared to the control group.

The study by Bracho and Adamuz (2014) was investigated the results obtained by individual cases of students with specific educational needs. The main target was to analyze the number sense proficiency, paying particular attention to the different rates of learning existing in the classroom. Among the participants in the experimental group the results were considered effective, considering that some students had a limited intellectual capacity, or autism spectrum disorders.

Regarding the acquisition of numerical sense, it is necessary consider what cognitive processes are necessary to enable its development. The meta-analysis conducted by Peng, Namkung, Barnes, and Sun (2016), after 110 studies, concludes that working memory has a strong relationship with problem solving and calculation, especially students with learning difficulties in mathematics. Rubinsten and Henik (2009) pointed out that the learning difficulties of mathematics should originated from a deficit in general domain cognitive abilities, such as working memory, the fluid intelligence or processing visuospatial (Aragón et al., 2015). Less conclusive are shifting and inhibition of irrelevant information skills (Bull & Lee, 2014). Consequently, a method which will provide a considerable gain in math skills and coping with the difficulties in this school tasks, should bring a cognitive benefit, or developing skills for contributing to an efficient general performance.

While ABN method started in our school context in 2008, contrasted studies linking this approach to cognitive performance parameters involved in mathematics learning at an early age are necessary. The confluence of two different methods of teaching mathematics in our school context, allows us to compare differences in cognitive profiles of students in each. In this sense, the main target of the study was to compare how cognitive processes operate in both ABN and CBC methods. Specifically, first, we studied the working memory, short-term verbal and visuospatial memory, and fluid intelligence, associated with the ABN method for teaching mathemat-