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Effectiveness of the Building Blocks program for enhancing Ecuadorian kindergartners' numerical competencies

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ABSTRACT

We investigated the effectiveness of the Building Blocks program for enhancing Ecuadorian kindergartners' early numerical abilities and spontaneous focusing on numerosity (SFON), after controlling for working memory, intelligence, age, and SES. Following a pretest-intervention-posttest design, 18 classes comprising 355 children from varied SES backgrounds were randomly assigned to either an experimental (BB program) or a control (regular mathematics program) condition. Results showed that the children from the experimental group made more progress in their early numerical competencies than those from the control group. Furthermore, the BB program was associated with higher quality mathematics education. We discuss the theoretical and educational implications for early numeracy development in general, and for the Ecuadorian situation in particular.

1. Introduction

Early numerical competencies are of major importance for children's further numerical and mathematical development (Aunio & Niemivirta, 2010; De Smedt, Verschaffel, & Ghesquière, 2009; Hannula-Sormunen, Lehtinen, & Räsänen, 2015; Hannula, Lepola, & Lehtinen, 2010; Hannula, Rasanen, & Lehtinen, 2007; Jordan, Kaplan, Ramineni, & Locuniak, 2009). It is increasingly emphasized that these competencies include both children's early numerical abilities (e.g., their ability to count, to compare numerical magnitudes or to decompose numbers) and their numerical dispositions (e.g., their spontaneous inclination to focus on and make sense of the numerical magnitudes in the situation) (Bojorque, Torbeyns, Hannula-Sormunen, Van Nijlen, & Verschaffel, 2017; Mulligan et al., n.d.). Children's early numerical abilities (Aunio & Niemivirta, 2010; De Smedt et al., 2009; Jordan et al., 2009) as well as their early numerical dispositions — more specifically, their spontaneous focus on numerosities or SFON, defined as children's natural tendency to spontaneously focus attention on the aspect of the exact number of items or incidents when exact numerosity is utilized in action (Hannula-Sormunen et al., 2015; Hannula & Lehtinen, 2005; Hannula et al., 2010, 2007) — were shown to contribute to children's later mathematical performance at school.

1.1. Contribution of background and domain-general cognitive characteristics

Children's early numerical abilities have been shown to be moderated by several domain-general cognitive characteristics and background characteristics. With respect to the domain-general cognitive characteristics, working memory and intelligence have shown to play a central role in the acquisition of early numerical abilities (Bull, Espy, & Wiebe, 2008; Friso-van den Bos, van der Ven, Kroesbergen, & Van Luit, 2013; Geary, Hoard, & Nugent, 2012; Passolunghi, Lanfranchi, Altoè, & Sollazzo, 2015; Swanson, Jerman, & Zheng, 2008). As reported in the review of Friso-van den Bos et al. (2013), children's working memory capacity is closely related to their mathematics performance and predicts proficiency in mathematics achievement at seven years of age. In the same proposition, Passolunghi et al. (2015) found that kindergarteners' verbal intelligence was directly associated with their early numerical abilities.

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Furthermore, intelligence and working memory measured at Grade 1, 2, and 3 were shown to contribute to children's accuracy in mathematical word problem solving two years later (Swanson et al., 2008). Similarly, Geary et al. (2012) found that intelligence and working memory assessed in kindergarten were associated with the complexity and accuracy of children's addition strategies at the beginning of first grade. Thus, stronger intelligence and working memory capacity measured in kindergarten are associated with more sophisticated arithmetic and mathematical abilities. To the best of our knowledge, evidence on the relation between children's SFON and their intelligence or working memory capacity is currently missing.

With respect to background characteristics, age and SES play an important role in the acquisition of children's early numerical abilities. It was observed that children who started kindergarten at an older age had an advantage over younger children in early numerical abilities (Jordan et al., 2009). Similarly, previous studies reported that young children from disadvantaged SES backgrounds, on average, have weaker mathematical knowledge and skills than their peers from middle SES backgrounds (Clements & Sarama, 2011a; Jordan et al., 2009; Siegler & Ramani, 2008; Starkey, Klein, & Wakeley, 2004). These early difficulties in the acquisition of early numerical abilities are of great concern, as these children are at risk to continue to perform weakly during formal schooling (Jordan et al., 2009). Although prior SFON studies have included children from various SES backgrounds (e.g., Hannula et al., 2010), they did not systematically investigate the relation between SES and SFON.

1.2. Early mathematics programs

Given the difficulties of children from disadvantaged SES backgrounds, several mathematics programs have been developed to stimulate the development of the early numerical abilities of (especially these) children, including Number Worlds (Griffin, 2007), Pre-K Mathematics (Klein, Starkey, & Ramirez, 2002), Big Math for Little Kids (Ginsburg, Greenes & Balfanz, 2003), and Building Blocks (Clements & Sarama, 2013). Intervention studies evidence the effectiveness of these programs for enhancing the early numerical abilities of 4- and 5-year-old children from low SES backgrounds (Clements, Sarama, Spitler, Lange, & Wolfe, 2011; Griffin, 2005; Lewis Presser, Clements, Ginsburg, & Ertle, 2015). Additionally, Ramani, Siegler, and Hitti (2012) demonstrated that playing linear board games (e.g., The Great Race) in small groups during 20–25 min for 3–4 weeks improved early numerical abilities of 3- to 5-year-old children from low SES backgrounds from Head Start classrooms. Finally, it is worth noting that all the intervention studies reported here have been performed, so far, only in developed countries where the primary language is English.

In this study, we will focus on one of these programs, namely the Building Blocks (BB) program,[1] for the following reasons. First, it was developed based on a comprehensive Curriculum Research Framework and structured in research-based learning trajectories (Clements, 2007). Second, it also includes an appropriate professional development program for teachers, emphasizing teaching for understanding via these learning trajectories. By using an observational instrument that measures the quality of the mathematics environment and activities, namely the Classroom Observation of Early Mathematics Environment and Teaching (COEMET; Sarama & Clements, 2009b), Clements et al. reported that the professional development program helped teachers to increase the quality of their mathematics classroom environment and teaching practices (Clements & Sarama, 2008; Clements et al., 2011). Third, empirical evidence supports the effectiveness of the BB program for enhancing young children's early numerical abilities. In this respect, previous studies demonstrated that prekindergarten children who received the BB program outperformed their peers not involved in this program in general mathematics achievement and early numeracy tasks (Clements & Sarama, 2007, 2008; Clements et al., 2011). These positive effects of the BB program on children's mathematics achievement persisted in kindergarten (Sarama, Clements, Wolfe, & Spitler, 2012) and first grade (Clements, Sarama, Wolfe, & Spitler, 2013). Furthermore, children in the BB classes performed better than the control children in oral language subtests (Sarama, Lange et al., 2012). Fourth, and finally, as a complement of the BB program, the same research team created the Fidelity of Implementation (Fidelity) instrument (Sarama & Clements, 2012), a measure of implementation fidelity that evaluates the degree to which teachers are accurately teaching the BB program.

1.3. The Building Blocks program

The BB program's basic approach is ". . . to find the mathematics in, and develop mathematics from children's experiences and interests" (Clements & Sarama, 2013, p. T13). Its activities are based on the developmental levels of mathematics learning trajectories and are carefully designed and sequenced to address each level of the learning trajectory. Learning trajectories refer to children's natural developmental progression in learning mathematics. They include three important elements: (1) a mathematical goal, defined as an aspect of a mathematical domain that children should learn; (2) a developmental path, describing the development of children's levels of thinking to reach that mathematical goal; and (3) a set of instructional activities, indicating how to help children move along that developmental path (Clements & Sarama, 2004).

The program addresses five mathematical areas: (1) number, (2) geometry, (3) measurement, (4) patterns and early algebra, and (5) classifying and analyzing data. In this study we focused on the area of number. This area includes (1) counting, (2) comparing and ordering, (3) recognizing numbers and subitizing, (4) composing numbers, (5) adding and subtracting, and (6) numerals. The program consists of daily lessons, in which children are guided to explore, represent and discuss mathematics through activities and games in the whole group, in small groups, in free-choice learning centers, and during reflection time. Important components of the program are the use of technology, permanent assessments, family involvement, and the inclusion of so-called "mathematics throughout the year" activities (i.e., activities that help to integrate mathematics into daily classroom practices). An example of the latter activities is called *I see numbers* where teachers try to help children see groups of one, two, and three everywhere and in every opportunity they have along the day, such as three Trees – not just a group of Trees – "helping them form the habit of quantifying small collections" (Clements & Sarama, 2013, p. 3), a concept closely related to children's SFON as acknowledged explicitly by the authors (Sarama & Clements, 2009a).

1.4. The present study

Although important, all previously mentioned intervention studies (Clements et al., 2011; Griffin, 2005; Lewis Presser et al., 2015; Ramani et al., 2012) have some limitations. Firstly, they focused on systematically evaluating children's early numerical abilities, leaving aside their dispositions to attend to and make sense of numerical magnitudes, including SFON. As mentioned above, SFON has shown to play a pivotal role in the development of young children's early numerical competencies and has demon-

[1] As explained in Section 2, we were only able to implement the core BB program but not the software activities. Moreover, in our measurements we only looked at its effectiveness for children's early numerical competencies and, thus, not at their broader mathematical development.