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Does the Opportunity–Propensity Framework predict the early mathematics skills of low-income pre-kindergarten children?

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ABSTRACT

Prior studies have shown that the variables described in the Opportunity–Propensity (O–P) Framework have successfully accounted for the mathematics and science achievement of students in grades 1–3 and 8–12. The two goals of the present study were to (1) determine whether the O–P Framework could also account for individual differences in the early mathematics skills of low-income, pre-kindergarten children and (2) determine whether latent variables constructed from measured variables would account for performance in the manner specified in the O–P model. The O–P Framework assumes that high achievement in mathematics is a function of three categories of factors: (a) antecedent factors, variables that operate early in a child's life and explain the emergence of opportunities and propensities, (b) opportunity factors, variables that measure a child's opportunity to learn mathematics content at home and school, and (c) propensity factors, variables that capture a child's propensity for learning in terms of self-regulation, motivation, and prior cognitive skills. To test the fit of this model for low-income children during the year before they attend kindergarten, the authors conducted a secondary analysis of achievement and background data from the Early Childhood Longitudinal Study-Birth (ECLS-B) Cohort data set. Structural equation modeling indicated significant associations between the antecedent factor, opportunity factor, and propensity factor, and between the opportunity factor and pre-kindergarten mathematics achievement. The results confirmed the fit of the model and identified the kinds of learning experiences that could promote the acquisition of mathematics skills in low-income children and improve their readiness to learn in first grade and beyond.

1. Introduction

The number of young children from low-income families who attend pre-kindergarten programs (e.g., preschool or daycare) in the United States is on the rise (see National Institute for Early Education Research (NIEER), 2011; U.S. Department of Education (USDOE), National Center for Education Statistics (NCES), 2000), reaching almost 6 million and representing 48% of all children under age three in the United States (see Addy & Wight, 2012). Low-income children are at risk for a host of early and prolonged academic and social disadvantages. This includes risks of lower academic achievement (see for example, Jordan, Kaplan, Ramineni, & Locuniak, 2009; Lee & Burkam, 2002), academic failure (Duncan, Yeung, Brooks-Gunn, & Smith, 1998), being placed in special education programs (National Research Council, 2002; Zhang & Katsiyannis, 2002), and being under-employed later in life as adults (Baydar, Brooks-Gunn, & Furstenberg, 1993; Senechal, LeFevre, Thomas, & Daley, 1998). Research suggest that very early opportunities to learn mathematics can promote the development of fundamental mathematics skills and knowledge during pre-kindergarten years (National Association for the Education of Young Children (NAEYC), 2002; Ramani & Siegler, 2008; Starkey, Klein, & Wakeley, 2004), and that mathematics achievement is among the strongest predictors of later academic success (Duncan et al., 2007). Despite the increasing focus on early math skills, little is known about the relationship between greater exposure to typical pre-kindergarten mathematics activities and the mathematics achievement of this particularly vulnerable group of children. By understanding whether low-income pre-kindergarten children would benefit from greater exposure to typical pre-kindergarten mathematics activities, policymakers, educators, and parents would learn whether our current pre-kindergarten programs can provide an opportunity to strengthen the mathematics skills of this growing population of children and improve their readiness to learn in first grade and beyond.

Although mathematics achievement has been found to be one of the strongest predictors of academic success (Duncan et al.,

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2007) and mathematics performance in primary and secondary grades (Aubrey, Dahl, & Godfrey, 2006; Aunio & Niemivirta, 2010; Byrnes & Wasik, 2009; Hooper, Roberts, Sideris, Burchinal, & Zeisel, 2010), there is less agreement on the factors that promote the development of early mathematics knowledge and skills prior to kindergarten (see Bowen, Gibson, & Hand, 2002; Hillemeier, Morgan, Farkas, & Maczuga, 2010; Pintrich, 2000; Ramani & Siegler, 2008). Some evidence suggests that very early opportunities to learn mathematics can promote the development of fundamental mathematics skills and knowledge during pre-kindergarten years (National Association for the Education of Young Children (NAEYC), 2002; Starkey et al., 2004; Ramani & Siegler, 2008), particularly since pre-kindergarten children tend to have fewer opportunities to learn mathematics than literacy at home (Tudge & Doucet, 2004). In response, a number of researchers (see Chard et al., 2008; Clarke et al., 2011; Clements & Sarama, 2007, 2008; Clements, Sarama, Spitler, Lange, & Wolfe, 2011) conducted randomized or quasi-experimental studies on comprehensive, structured early mathematics curriculum to see the impact of these programs on the early math knowledge of children from low-income families. Not surprisingly, these studies have found that students who had the structured early math curricula scored significantly higher than students from comparison or control groups with an average effect size of 0.85 as measured by Cohen's *d* (see Chard et al., 2008; Clarke et al., 2011; Clements & Sarama, 2007, 2008; Clements et al., 2011).

However, most pre-kindergarten curriculum on mathematics are not structured and consisted mostly of activities that can be roughly grouped into activities relating to counting, shape identification, the identification and completion of repeating patterns, and integrated activities, where mathematics were integrated in everyday activities such as music, creative movement, and cooking (Greenes, Ginsburg, & Balfanz, 2004). While many researchers have criticized that the typical mathematics programs at the pre-kindergarten levels are limited (Clements & Sarama, 2007; Greenes et al., 2004), emerging evidence suggests that children from low-income families may have differential exposure to mathematics learning opportunities during the early school years (Wang, 2010), and more evidence is needed to understand the relationship between differential opportunities to learn mathematics and mathematics learning for pre-kindergarten children from low-income families.

Moreover, another body of research points to children's self-regulation (Duckworth & Seligman, 2005; Ponitz, McClelland, Matthews, & Morrison, 2009), motivation (Pintrich, 2000), and propensity for learning (Byrnes & Wasik, 2009) as strong predictors of mathematics skills and knowledge. Additionally, there is another large body of research that suggests there are a number of factors, such as low birth weight (Bowen et al., 2002; Hillemeier et al., 2010; Sajaniemi et al., 2001), poor early cognitive functioning (Cooper & Schleser, 2006), and low parental expectations (Fehrmann, Keith, & Reimers, 1987; Rutchick, Smyth, Lopoo, & Dusek, 2009), that put low-income children at greater risk of academic failure than their more affluent peers. The purpose of the present study was to test a hypothesized structural model of predictors that includes many of these factors, linking antecedent factors (those that occur early in a child's life) to opportunity to learn mathematics and propensity for learning, and, in turn, linking opportunity to learn mathematics and propensity for learning to low-income children's pre-kindergarten mathematics skills and knowledge.

1.1. Theoretical foundation

As noted above, researchers in early childhood have identified a number of factors associated with readiness to learn and achievement. And increasingly, researchers have taken a multivariate approach to predict achievement in which they demonstrated the independent effect of an important construct such as behavioral or emotional regulation while controlling for several other key predictors such as parent education and prior achievement (e.g., Howse, Calkins, Anastopoulos, Keane, & Shelton, 2003; McClelland et al., 2007). While much has been learned from these studies, it is important to extend this work in several ways. First, whereas the aforementioned multivariate studies investigated more factors than researchers typically examined in the past (e.g., four to seven variables instead of one or two), the list of unique, significant predictors of achievement extends well beyond the set analyzed in these studies. Second, and more importantly, most of the multivariate studies have not organized the set of significant predictors into a coherent and comprehensive explanatory framework. Instead, their goal was to demonstrate the unique role of one or two of the factors examined (e.g., behavioral regulation). Constructing an explanatory framework is the first step in designing more effective forms of intervention to elevate the performance of low-income children and get them ready for school. In the absence of effective and more stringent controls for powerful and authentic predictors, intervention efforts may be directed toward a variable that is less related to outcomes than it appears. In addition, an accurate comprehensive account that lays out factors in a temporally arranged manner would help interventionists to understand what to target and when. This approach of identifying most of the significant predictors and arranging them into a proposed explanatory framework is not unlike what occurs in medical epidemiological work (e.g. identifying the various predictors of heart disease, such as cholesterol levels and exercise).

The present study utilized the Opportunity–Propensity (O–P) Framework (Byrnes, 2003; Byrnes & Miller, 2007; Byrnes & Wasik, 2009; Jones & Byrnes, 2006; Sackes, Trundle, Bell, & O'Connell, 2011) to study the impact of pre-kindergarten opportunity to learn mathematics and propensity for learning on pre-kindergarten mathematics achievement. To our knowledge, the O–P Framework is the only available theoretical model that effectively combines all of the factors assessed in this and a number of other recent studies. It was specifically designed to explain why some children (e.g., White students) perform significantly better than others (e.g., Black students) on achievement measures. The opportunity component of the O–P Framework refers to variables such as teacher-initiated opportunities to count out loud, use geometric or counting manipulatives and play mathematics games, that offer a context to learn academic content. The propensity component refers to variables such as previous knowledge and achievement motivation that increase the likelihood of children benefiting from opportunities to learn (Byrnes & Miller, 2007; Byrnes & Wasik, 2009). The Opportunity–Propensity Framework suggests that children are more likely to realize their potential for learning a particular subject matter such as mathematics if they are provided opportunities to learn that content at school and in other contexts and have the motivation and capability to benefit from the opportunities provided to them (Byrnes & Wasik, 2009). For low-income children, having school-based or teacher-initiated exposure to mathematics at the pre-kindergarten level is especially relevant and important, given that they are particularly at risk for entering kindergarten and first grade with significantly lower mathematics skills and knowledge than their peers (see Duncan et al., 1998; Jordan et al., 2009). In this framework, variables such as parent expectation and maternal education are considered as indicators of the antecedent factor. The antecedent factor explains why some pre-kindergarten children are more likely than others to benefit from the opportunities provided to them and develop stronger propensities for learning (Byrnes & Wasik, 2009). The antecedent factor can also be used to account for the variation in the outcome variable, allowing for the unique contributions of the propensity factor