

Chapter 2

Early Mathematical Development: How the Home Environment Matters

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While the origins of some of early mathematical skills may be innate, experience plays a significant role in how children's mathematical skills develop (Geary, Berch, & Koepke, 2015). Researchers have examined the role of experience in the development of early mathematical skills using multiple methods such as training studies (e.g., Gelman, 1982; Siegler, 1995), intervention studies (e.g., Clements, Sarama, Wolfe, & Spitler, 2013), and comparisons of different groups based on language background (e.g., Miura & Okamoto, 2003), culture (e.g., Saxe, Dawson, Fall, & Howard, 1996), and socioeconomic status (e.g., Ginsburg & Russell, 1981). Only more recently has the home numeracy environment and the experiences it provides received concentrated attention. This attention is consistent with the emphasis on the social environment that sociocultural theory (Vygotsky, 1978) places on the role of adults in training children on the use of cultural tools as well as the growing body of evidence that indicates both that mathematical development begins well before children enter formal schooling and that early mathematical skills lay the foundation for mathematics achievement in school (Watts, Duncan, Siegler, & Davis-Kean, 2014).

This chapter will review the literature on home numeracy and identify the underlying theoretical assumptions that have guided the research. Parents are a major influence on the home numeracy environment and much of the research has focused on parental attributes such as behaviors, attitudes, and beliefs, as causal indicators. It will be argued that we need new ways to conceptualize both the role of parents and the interactive and constantly changing relationship between parents and their children.

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Brief History of Home Numeracy Research

Before reviewing the history it is necessary to address one of the consistent inconsistencies in the home numeracy literature and that is the manner in which the term “mathematics” is employed. In many studies the focus is on children’s number skills rather than the full range of mathematical skills. While it is the case that number skills are a subset of mathematical skills often authors use both terms, sometimes interchangeably. For example, it is common to measure only children’s number skills, yet discuss children’s mathematical performance. Because of the difficulty inherent in sorting through this inconsistent use, this chapter will continue the practice of using “mathematics” to refer to both. However, as the field evolves, it will be necessary to be more consistent in communicating whether only children’s numerical skills are involved or the broader range of mathematical skills when examining the effects of the home environment.

Three streams of research have guided the study of the effects of the home numeracy environment. Each of these three streams of research contributes support for the conclusion that children’s early environments influence their cognitive development. The first examined the influence of parents on children’s cognitive development and academic achievement (e.g., Alexander & Entwisle, 1988; Eccles et al., 1993; Goodnow & Collins, 1990). The second, and related research stream, examined the effects of the home environment on children’s cognitive development as measured by the Home Observation for Measurement in the Environment (HOME) inventory (Bradley, 2010; Caldwell & Bradley, 1984). The third examined how the home literacy environment influenced the development of literacy (e.g., Sénéchal & LeFevre, 2002).

Early studies on the effects of the home environment on children’s number skills described the home numeracy environment and established a connection with children’s performance. Both Durkin, Shire, Riem, Crowther, and Rutter (1986) and Young-Loveridge (1989) employed very small samples and provided a description of the home numeracy environment. Durkin et al. (1986) examined mothers and infants (9–36 months) use of number words. They noted that, as expected, mothers more frequently used number words than their infants did. However, because in some cases input from the mothers presented conflicting information, it is unclear how much influence their efforts had on number word use in infants. The researchers stressed that it is only by studying the interaction between mother and child that the value of the interaction can be understood and its impact on numeracy established. Employing a slightly different age group, Young-Loveridge (1989) linked home numeracy activities to preschool children’s performance. Through a case study approach she found that the variety of number activities occurring in home environments correlated with children’s performance on number tasks.

Saxe, Guberman, and Gearhart (1987) focused on the influence of the social aspects of the home environment on numeracy. They included a larger sample and interviewed working and middle-class mothers about expectations for their

children's numerical success and about daily activities involving numbers. In addition, they observed mothers teaching their children about counting while playing a game. Mothers from the middle class reported engaging in more complex numerical activities and had higher educational aspirations for their children than mothers from the working class. Children from the middle class had a higher level of numerical performance.

As more home numeracy research was conducted an ensuing common thread in research was the connection between parent-child activities and children's performance on number tasks. Anderson (1997) observed parents and preschool children interacting with a set of play materials and found that counting was the most frequent activity. The types of activities she observed were a function of both the play materials and the approaches taken by the parents. Huntsinger, Jose, Liaw, and Ching (1997) addressed the effects of the social environment from a cross-cultural perspective. They examined the influence of parents' beliefs, attitudes, expectations and reported teaching behaviors on children's numerical performance for children from three ethnic backgrounds: Chinese-American, Euro-American, and Taiwan-Chinese. Differences in children's performance were predicted by differences in parent's child-specific attitudes and parents' reported teaching style. The more direct teaching techniques and more positive attitudes about mathematics reported by the Chinese-American and Taiwan-Chinese parents were significant predictors of children's mathematics performance.

Blevins-Knabe and Musun-Miller (1996) sought to identify specific activities in the home environment that supported children's number development. Parents' reports of the frequency of mathematical activities that occurred in the home were correlated with a global measure of children's numerical understanding. In addition, children's performance on some of the individual number tasks was correlated with parents' reports of the frequency of that activity in the home. In some cases the correlations were positive, including items that involved the use of small number words and the mention of number facts, and in some the correlations were negative, including items that involved parents teaching basic concepts.

The early work on the home numeracy environment provided evidence that the home environment was indeed correlated with children's performance. Two unanswered questions were as follows: are there core features of the home environment that influence all types of cognitive development, including mathematical development?, and are there features of the home environment that have a unique relationships to mathematical development?

The results of the early studies were also consistent with the emphasis that the research on children's cognitive development places on the role of parents. Parents have a major influence in shaping both the physical and social environment for young children. However, while children's characteristics were often included in the early numeracy research rarely were children themselves included as active contributors and shapers of their own development and social environment.

More Recent Rationales for Studying the Home Numeracy Environment

A review of studies conducted on the effects of home numeracy from 2000 until the present shows that while their rationales are consistent with the goals of earlier research, their focus has broadened in scope, and can be condensed to four major themes. First, because strong mathematical skills are necessary for the economic success of both individuals and nations we need to understand what influences their development (Melhuish et al., 2008; Skwarchuk & LeFevre, 2015; Tudge & Doucet, 2004). Second, children in the United States are behind children of other nations in their math skills therefore we need to understand the influences on mathematical development (Pan, Gauvain, Liu, & Cheng, 2006). Researchers from the United States are most motivated by this one (e.g., Huntsinger, Jose, Larson, Krieg, & Shaligram, 2000) Third, early numeracy skills predict later academic performance in school (Duncan et al., 2007) so we need to understand the influence of the home environment (e.g., DeFlorio & Beliakoff, 2015; Huntsinger, Jose, & Luo, 2016; Kleemans, Peeters, Segers, & Verhoeven, 2012; LeFevre et al., 2009; Manolitsis, Georgiou, & Tziraki, 2013; Melhuish et al., 2008). This argument is based on assumptions that early numeracy skills predict later skills, that early experiences matter, and that for young children the home environment is the primary environment that influences the development of early mathematical skills. A variant of this argument is that since the home environment in the preschool years has been linked to children's literacy skills it is reasonable to predict that the home environment will influence early numeracy skills (LeFevre et al., 2009; LeFevre, Polyzoi, Skwarchuk, Fast, & Sowinski, 2010; Lukie, Skwarchuk, LeFevre, & Sowinski, 2014; Niklas & Schneider, 2013). The fourth rationale for research on home numeracy is the premise that the quality of the home environment may account for the variation in the mathematical performance of preschool children (Anders et al., 2012; Benigno & Ellis, 2004; Cannon & Ginsburg, 2008; Dilworth-Bart, 2012). Some, such as Ramani, Rowe, Eason, and Leech (2015) and Missall, Hojnoski, Caskie, and Repasky (2015), noted that children from low-income families enter school with lower levels of math skills and suggested that variations in the home numeracy environment may be a factor.

What We Have Learned About the Home Numeracy Environment

Researchers have employed a variety of methods when measuring the home environment. A common method is to use parental reports of the frequency of number activities occurring in the home, both with and without the parent (Blevins-Knabe, Austin, Musun, Eddy, & Jones, 2000; Blevins-Knabe & Musun-Miller, 1996; DeFlorio & Beliakoff, 2015; Kleemans et al., 2012; LeFevre et al., 2009, 2010;

Melhuish et al., 2008; Missall et al., 2015; Pan et al., 2006; Ramani et al., 2015; Skwarchuk, 2009; Skwarchuk & LeFevre, 2015; Skwarchuk, Sowinski, & LeFevre, 2014). However, in most of these studies the relationship between home activities and children's number skills is inconsistent. Some researchers have reported no correlations at all (Blevins-Knabe et al., 2000; Missall et al., 2015), others no correlations with indirect home numeracy activities such as playing games involving numbers or cooking (LeFevre et al., 2010), and still others found significant effects when numeracy activities were included in regression analyses (DeFlorio & Beliakoff, 2015).

In these studies activities which are reported to occur daily or almost daily include naming shapes (Missall et al., 2015), counting objects in a group (Missall et al., 2015; Skwarchuk, 2009), counting out a certain number of objects from a group (Missall et al., 2015), teaching the child to count (Blevins-Knabe & Musun-Miller, 1996; LeFevre, Clarke, & Stringer, 2002; Manolitsis et al., 2013), using spatial words to describe location (Missall et al., 2015), using the words '1,' '2,' or '3' (Blevins-Knabe & Musun-Miller, 1996), and praising one's child for using numbers (Blevins-Knabe & Musun-Miller, 1996). The majority of these activities involved counting, which is one of the better known and easy to observe number activities in the early years.

There is no defined benchmark for how frequently home numeracy activities need to occur to have an effect on the development of children's mathematical skills. In addition, it is still unclear whether the frequency of math-related activities in the home is a useful indicator of the relationships between home numeracy and young children's mathematical development. However, before addressing these questions, research that employed different methodologies to examine number activities in the home numeracy environment will be reviewed in order to determine whether the patterns of results are similar.

Anders et al. (2012) created a measure of the home learning environment with two scales, one for literacy and one for numeracy. Both scales included relevant items from the HOME (Caldwell & Bradley, 1984) and a rating of numeracy or literacy-relevant parent-child interactions during a reading task. Their sample included German children who were studied longitudinally from 3 to about 5½ years. Children's mathematics performance was measured using a standardized measure of arithmetic that included identification of shapes. Anders et al. (2012) report that literacy activities were more frequent than numeracy activities and that the home literacy environment activities predicted children's numeracy skills better than did the home numeracy environment activities. In a second study using the HOME Dilworth-Bart (2012) found that SES mediated the effects of executive function on the math performance of 4- and 5-year-olds, but the HOME was not a significant mediator. Unfortunately, because the items from the HOME provide a different scale than measures of frequency of numeracy activities used in other studies it is not possible to directly compare these results to those of others; however, the Anders et al. results are consistent with the findings that home numeracy activities are relatively infrequent.

Another methodology for examining the frequency of numeracy behaviors in the home is to observe parents (usually mothers) interacting with their children in

games or other activities provided by the researchers. Vandermaas-Peeler and her colleagues have conducted several observational studies of preschool children in the United States and their mothers playing with toys or games, and reading (Vandermaas-Peeler, Ferretti, & Loving, 2012; Vandermaas-Peeler, Nelson, & Bumpass, 2007; Vandermaas-Peeler, Nelson, Bumpass, & Sassine, 2009; Vandermaas-Peeler & Pittard, 2014). The context in which the activity occurs, socioeconomic status of the parents, and instructions to the parents all correlated with the frequency of numeracy behaviors. Parents were more likely to initiate numeracy interactions during play than during reading (Vandermaas-Peeler et al., 2009), and when given suggestions about numeracy activities (Vandermaas-Peeler, Ferretti, et al., 2012). Although both low- and high-SES mothers were similar in how often they initiated interactions about the uses of numbers in daily life (e.g., cooking, value of money, etc.), high-SES mothers were more likely to initiate mathematical interactions (e.g., counting, asking how many, etc.) than low-SES mothers (Vandermaas-Peeler et al., 2009).

Further support for the conclusion that context influences parental behaviors comes from Benigno and Ellis (2004) who examined the effect of the presence of an older sibling. They observed middle-class parents in the United States playing a board game with their preschool child with and without the presence of an older sibling. When an older sibling was present fewer numeracy activities occurred. In the absence of the sibling, preschool children counted more and the parent provided more instruction and modeling.

These studies show that in structured observational contexts numeracy interactions occur between parents and young children. Yet the studies do not directly address the issue of how often these interactions occur. For example, Ramani et al. (2015) addressed the frequency of numeracy interactions by recording the math talk between caregivers and their children from low-SES backgrounds in the United States. Caregivers played with toys selected to facilitate talking about math. The amount of math talk that occurred was low even with the toys as prompts. The relatively low frequency of math talk reported by Ramani et al. (2015) and the influence of context reported by Vandermaas-Peeler and colleagues (Vandermaas-Peeler, 2008; Vandermaas-Peeler, Boomgarden, Finn, & Pittard, 2012; Vandermaas-Peeler, Ferretti, et al., 2012) and Benigno and Ellis (2004, 2008) indicate that scaffolding children's mathematical development may not be a priority when the parent is the child's social partner. Parents may be more likely to provide support for math in situations with fewer competing demands, or in situations in which there are not competing academic activities such as reading.

While structured observational studies show what parents can do, for example, provide direct instruction about math and engage in talking about numbers, the question that is unanswered is what they do—what actually happens in the everyday environment. Instead of relying on parental reports, the most direct way to assess frequency of home numeracy activities in the home is to observe parents and children at home. Tudge and Doucet (2004) and Tudge, Li, and Stanley (2008) argue that studies that are laboratory based or done using structured observations lack information about what happens in everyday life. They criticize parental reports

because parents may not know everything that happens in a child's life or may think some activities are unimportant. Tudge and Doucet observed middle and working class white and black children in the United States over the course of a week and found wide variation in the number of mathematics activities between children. For the most part, children engaged in few activities for either literacy or mathematics that involved either direct instruction or requests for information. However, children engaged in more literacy play than math play.

Agreement about a common standard for gauging a meaningful frequency level of activities does not exist. Furthermore, the question of what is the optimal frequency for home numeracy activities is still unresolved. However, some insights into how to think about what is critical about home numeracy activities, whether it is frequency or some other variable, comes from Hunt's (1961) concept of a match between the environment and children's level of development. Wachs (2005) presents a more recent formulation of this match called the person-environment fit. A good fit between the child's level of development and what the environment offers optimizes development. A mismatch can impede progress. In order to understand an optimal match it is necessary to understand the environmental context as well as the characteristics of the individual. The conceptual models that guide research on home numeracy provide some insight about the contextual (environmental) features of the home environment that influence children's mathematical development.

Before introducing these conceptual models, differing central assumptions of Piaget's and Vygotsky's theories concerning the role of the social environment and children's role in development will be outlined. Piaget's theory, in particular, focuses on the development of the individual and provides guidance as to the child's role in development. Vygotsky's theory switches the emphasis to the external environment as a trigger for developmental change. The different emphases of these theories can help highlight key issues that are useful in evaluating the conceptual models.

Differing Foci of Piaget and Vygotsky

Both Piaget's and Vygotsky's theories have been central to research about the role of experience in children's mathematical development. Despite the misconception that Piaget downplayed the role of the social environment, his position was that children learn from all of their experiences, material and social (Tudge et al., 2008). Furthermore, while parents and others can influence children's development, direct teaching is not necessary or required. Piaget's emphasis was on how new knowledge is generated rather than on how knowledge is transmitted (Chapman, 1988). In contrast, Vygotsky put more emphasis on the transmission of information from social agents while acknowledging the contribution the child makes to the interaction (Tudge et al., 2008).

Tudge et al. (2008) argue that this difference in focus between the theories may appear to be more meaningful than it is. Even when children initiate learning mathematics on their own they use materials provided by culture and interact with

members of the culture. However, Lourenço (2012) claims this difference in emphasis is fundamental and influences how we think about development. Specifically, he argues that for Piaget learning occurs due to the actions of the child so the source of development is within the child. In contrast, for Vygotsky learning comes from external agents and development is triggered by outside factors. We will need to explicitly address the sources of developmental change and the interaction between the child and social agents to achieve a deeper understanding of the effects of the home numeracy environment.

Conceptual Models of Home Numeracy

Focusing on external sources of change, Huntsinger et al. (1997, 2000) based much of their home numeracy research on Eccles' expectancy-value model (Eccles et al., 1993; Simpkins, Fredricks, & Eccles, 2012). Eccles' model draws from socialization theories (e.g., Goodnow & Collins, 1990; Maccoby, 1998), sociological research on the effects of family resources (e.g., Alexander & Entwisle, 1988), social cognitive theories (Bandura, 1997), and sociocultural theories (Rogoff, 1990). The Eccles' model highlights how parents' attitudes, expectations, beliefs, behaviors, and demographic characteristics influence child developmental outcomes. Huntsinger et al. (1997, 2000) found parents' attitudes and behaviors predicted children's mathematical performance, which is consistent with the predictions of the expectancy-value model.

Recently, Skwarchuk et al. (2014) proposed a model of home numeracy based on the home literacy model of Sénéchal and LeFevre (2002) that includes both parental attitudes and behaviors. Parental attitudes are predicted to have an indirect effect on children's numeracy performance through parents' behaviors, which have a direct effect. Home numeracy activities provided by parents fit one of two categories, either formal or informal. The goal of formal numeracy activities is to teach children about mathematics. In contrast, the goal of informal numeracy activities is not specific to mathematics, and any learning about mathematics that occurs is a by-product of other activities. Playing games is an example of an informal activity.

Neither model puts a primary focus on the child in the way that Piaget does as a constantly changing active seeker of knowledge, who is both an active contributor to the home environment as well as a participant in the opportunities it affords. Both Huntsinger et al.'s (1997, 2000) work based on the expectancy-value model and Skwarchuk et al.'s (2014) home numeracy model place emphasis on the role of the parent as the primary determinant of the home numeracy environment. In many ways, the expectancy value and the home numeracy models are complementary. The expectancy-value model provides a more general view of the proximal and distal influences on children's cognitive outcomes and the home numeracy model provides a more focused and in-depth view of the proximal influences on children's numeracy outcomes. The emphasis that both models place on the influence of parents on children's mathematical development is consistent with the emphasis of Vygotsky's theory on the influence of the external social world.

However, maintaining the central role parents play in the process, but reconceptualizing its impact on the home numeracy environment may bring issues of interaction and the child's contributions to development to the forefront. This reconceptualization can also integrate Piaget's emphasis on the child into our understanding of the home numeracy.

The Role of Parents

A consistent theme in the previously outlined rationales for research on the effects of the home numeracy environment is the wide variation in children's skills upon entry into formal schooling. In order to advance our understanding of this wide range in skills, we need to understand the interaction between characteristics of the child and the physical and social environment provided in the home by the parents. Although we often think of parents as teaching young children about math, Tudge et al. (2008) suggest that the critical role of the parent in the home numeracy environment might be a supportive, scaffolding, inquisitive role rather than a direct teaching mode. Some insights into the types of parental influence come from work conducted with the HOME.

The HOME instrument was designed to measure the quality of the home environment by identifying the stimulation and support parents provide. Bradley and Caldwell (1995) conceptualized the job of the parent as maximizing and regulating children's opportunities for learning. Bradley and Corwyn (2004, 2006) extended these concepts into what they called the "central tasks of parenting." Four of the tasks, stimulation, support, structure, and social integration, are relevant to the role that parents play in young children's mathematical development. While the tasks are interconnected, they do serve different functions. Stimulation involves parents providing contingent responses and providing children with new information that attracts their attention. Support involves providing social and emotional support and as well as motivation for learning. Structure involves making sure the learning environment is a good fit for the child. Parents can accomplish this by regulating learning activities so that they match the child's developmental level. Social integration addresses the child's connection to the culture and society and is the concept closest to that of guided participation (Rogoff, 1990), which originates from sociocultural theory.

These four tasks may serve to conceptualize and delineate the underlying characteristics of parental influences on children's mathematical development. A challenge parents and other adults face when trying to support and facilitate children's mathematical development is that much of the mathematical information in our world is implicit rather than explicit. Even though children are surrounded by relevant information they may need help accessing it. Ginsburg, Lee, and Boyd (2008) use "mathematize" to describe the process of connecting experience with mathematical principles. Children may benefit from having parents who "mathematize." Effective support and mathematizing are likely to be guided by the goals of the aforementioned tasks of parenting identified by Bradley and Corwyn (2004, 2006): stimulation, support, structure, and social integration. The following sections will

address how each of the four tasks of parenting can be applied to home numeracy research. Using them as an organizing construct can facilitate a more holistic and systemic view of the interactions between the physical and social characteristics of the home environment as provided by parents and young children's mathematical development.

Stimulation

The parenting task of stimulation includes parental teaching that either directly or indirectly influences children's learning. Both direct and indirect teaching can highlight mathematical information that is present in the environment and make it more visible to children. LeFevre et al. (2009) made a distinction between direct and indirect home numeracy experiences based on the intentionality of parents' teaching. Direct numeracy experiences involve intentional teaching about math. Indirect home numeracy experiences include informal activities that may provide opportunities for learning about math, but learning about math is not the primary objective. There is evidence that direct teaching is predictive of children's learning. Several studies have examined the direct teaching role that parents play (Blevins-Knabe & Musun-Miller, 1996; LeFevre et al., 2009; Manolitsis et al., 2013) and reported positive correlations between parents' teaching behaviors and children's numeracy performance.

Less structured indirect numeracy experiences also influence children's math performance. Niklas and Schneider (2013) measured the home numeracy environment through parental reports of how often they engaged in dice, counting, or calculation games with their kindergarten children. These indirect home numeracy activities predicted math performance both at the end of kindergarten and at the end of first grade. This was the case even though the measure of math performance contained more advanced items at first grade.

Comparisons of the effects of indirect and direct teaching provide conflicting results. Huntsinger et al. (1997) in a cross-cultural study asked about direct and indirect teaching practices. They found that Chinese-American parents engaged in more direct teaching of numeracy of pre-k and kindergarten children than either Taiwan-Chinese or Euro-American parents. Children who received more direct teaching from parents performed better on a test of early number skills. Huntsinger et al. (2000) also found that Chinese-American parents engaged in more formal teaching of math and their children performed higher on the measures of mathematical performance.

In contrast, LeFevre et al. (2009) measured the effects of both direct and indirect teaching for kindergarten, first, and second grade children and found positive correlations for indirect teaching and math performance and negative correlations for direct teaching experiences. Indirect teaching experiences included playing games that involved math and were correlated with math fluency and knowledge. Engaging in activities with number books provided an opportunity for direct teaching by parents and was negatively correlated with math fluency. However, in a later study,

LeFevre et al. (2010) found direct teaching by parents of Canadian and Greek kindergarten children predicted numeracy performance. Further evidence of the potential influence of direct teaching is provided by Pan et al. (2006). They interviewed American and Chinese mothers of 5- and 7-year-old children and found that Chinese mothers reported more direct teaching activities involving number knowledge. Their children also performed better on the measures of mathematical performance.

Reflecting on these results reveals underlying motivations and goals that might explain some of the apparently contradictory results. It is possible that parents engage in direct or indirect teaching for different reasons, which might explain differences in children's performance. For example, Huntsinger et al. (2000) found that Chinese American parents direct teaching practices predicted their children's math performance over a 4-year period starting in preschool. These parents intentionally taught their children about mathematics from an early age. Other parents may engage in direct teaching practices reactively when they notice their children are having difficulty. Some parents might purposefully choose to teach through games and physical materials and select those that have educational value. Bradley and Corwyn (2004) identify parental investment of resources as the underlying construct that influences parent's actions with respect to their children. The concept of parental investment applied to the home numeracy research suggests that parents' willingness and ability to spend their resources helping children learn math is a critical variable. This commitment may be as important as whether the activity is direct or indirect.

Structure

Another way that parents invest in their children's learning is by providing structure. As defined by Bradley and Corwyn (2004, 2006), structure involves ensuring that the learning environment is a good fit for the child. How effectively structure influences learning is determined by the degree of fit between what the child needs and the home environment. Several home numeracy studies address the level of support that parents provide. Skwarchuk (2009) focused on the level of complexity of the home number activities parents reported. For both 4- and 5-year-olds more frequent exposure to lower level number activities was negatively correlated with numeracy performance while exposure to higher level number activities was correlated with higher numeracy performance. Blevins-Knabe and Musun-Miller (1996), LeFevre et al. (2009), and Skwarchuk (2009) also found negative correlations with some number activities provided by parents. Pan et al. (2006) found that 5- and 7-year-old Chinese children performed more poorly on a task requiring proportional reasoning when their mothers instructed them on calculation. Huntsinger et al. (2016) reported a negative correlation between children's mathematics performance and informal home numeracy activities (activities that do not focus on teaching mathematics) in a sample of 4- and 5-year-olds. The post hoc explanation most frequently offered by all was that parents match their input to what their children

need, which is consistent with the findings of Saxe et al. (1987), Benigno and Ellis (2004), and Vandermaas-Peeler, Boomgarden, et al. (2012). In the cases of the negative correlations children who are performing more poorly may need more instruction. The literature suggests that parents are relatively skillful at providing an appropriate level of structure. However, we need further research to test the post hoc hypotheses, and to address whether the type of math task influences the level of structure parents provide, and whether there are cumulative developmental changes that can be connected to the level of structure provided.

Support

The parenting task of support as described by Bradley and Corwyn (2004, 2006) focuses on the socioemotional support parents provide to children. Parents build children's self-worth and connections to others by responding to children's emotional needs. They also aid children in developing emotional regulation. Early in a child's life parents' socioemotional support influences attachment and a child's developing sense of self but as children develop there are additional outcomes. Bradley and Corwyn (2004) identify the core outcome of socioemotional support as motivating children to engage in behaviors that are adaptive for their success both in the home environment and beyond. Among these adaptive behaviors one could include mathematical skills that are necessary for success in today's world. An example of the influence of socioemotional support on math performance is provided by Azmitia, Cooper, and Brown (2009) who conducted a longitudinal study of young Latino adolescents and the socioemotional support provided by parents. Parents' support, which included educational guidance and emotional support, was a better predictor of math grades than the support of siblings, friends, or teachers. Another example comes from Bradley, Caldwell, Rock, Hamrick, and Harris (1988) who found the score on the total school subscale in an elementary school version of the HOME correlated with both the children's math achievement and the emotional climate subscale.

Socioemotional support and its influence need more attention in the literature on home numeracy. Parent's beliefs can influence children's belief systems and motivation to engage in mathematics. This can occur through parental interactions as well as communications about their own attitudes and beliefs about math. Eccles et al. (1993) distinguished between more proximal influences on both children's performance and beliefs and more distal ones. Distal influences included parents' general beliefs about development, beliefs about children in general, parent's teaching strategies based on these beliefs, as well as general demographic characteristics. Examples of more proximal influences are parents' beliefs about their own children including predictions about their children's performance, explanations for their children's performance, specific behaviors such as teaching strategies tailored to their own children, and the provision of learning materials. Both proximal and distal beliefs can influence the type of socioemotional support parents provide children.

Studies of home numeracy have addressed both proximal and distal attitudes and beliefs and some have included measures that address the value parents place on math. One frequently reported result pertains to a distal belief about the relative importance of literacy and numeracy. Parents report that reading is more important for young children to learn than math. Musun-Miller and Blevins-Knabe (1998) asked parents of 4- and 5-year-old children about the relative importance of acquiring general knowledge, reading, social skills, and math. Parents said that all were more important than math. Skwarchuk (2009) and Cannon and Ginsburg (2008), using low- and middle-income samples, also report that parents said reading was more important than math.

Other parental distal beliefs that have been examined are their attitudes and beliefs about how children learn. LeFevre et al. (2009) asked parents of kindergarten children about their general expectations for success on number tasks that could be considered benchmarks. There was no connection between these expectations and children's performance. Missall et al. (2015) asked parents of White and Hispanic preschool children in the United States about a combination of proximal and distal beliefs and reported a correlation between parents' beliefs about math and home activities, but no correlation with children's actual performance. Conversely, DeFlorio and Beliakoff (2015) found that the beliefs of parents of 3- and 4-year-olds from low- and middle-SES backgrounds about the mathematical skills of the typical child did predict children's mathematical performance. Parents from middle-class backgrounds had higher expectations and held more accurate beliefs regarding the math skills of the typical child than did parents from lower class backgrounds.

In contrast to distal beliefs, proximal beliefs are more often related to children's performance. Skwarchuk (2009) found that Canadian 4- to 5-year-olds, whose parents who rated their own personal experiences in math positively, performed better on a numeracy assessment. Both Kleemans et al. (2012) and Segers, Kleemans, and Verhoeven (2015) asked parents for specific information about their child and found that parents' expectations for children's numeracy performance and the frequency of numeracy activities predicted the numeracy skills of kindergarten children. In longitudinal research Huntsinger et al. (1997, 2000) included Chinese American and Euro-American preschool and kindergarten children and found that parents' expectations about their child's success in math predicted their child's performance both initially and 5 years later.

However, other work has provided contradictory results. LeFevre et al. (2002) asked parents of preschool children about their expectations for their own children on number tasks that could be considered benchmarks. While parents' expectations were correlated with their reported teaching activities there was no correlation with their children's performance. A similar result was reported by Skwarchuk et al. (2014) who found that parents who had higher expectations for their children's numeracy performance used more advanced math activities but that there was only an indirect effect on children's symbolic number knowledge. Cross-cultural work by LeFevre et al. (2010) indicated that context has a role to play in the influence of parents' beliefs and attitudes on children's performance. They found parents' attitudes about math and their expectations for their children's learning directly predicted the

numeracy performance of Canadian kindergarten children. However, there was an indirect effect for Greek children since the effects of parents' attitudes were mediated by activities in the home numeracy environment.

Despite this mixed pattern of results, connections between parent attitudes, home numeracy activities, and children's performance appear to occur more frequently than not, and that these connections occur in diverse samples. Accounting for parental attitudes and beliefs increases our understanding of the contribution the home numeracy environment makes to children's mathematical development, moving beyond a limited focus on the types and frequencies of math activities. Using the parenting task of socioemotional support as a conceptual lens suggests a need for more research that includes measures of the emotional climate in the home numeracy environment. The research reviewed earlier demonstrates the relevance of including parents' emotions about math and their optimism and level of expectation for children's learning in the models of home numeracy.

Social Integration

Social integration addresses how parents connect their children to society through the use of social capital. Mathematics is a powerful cultural tool and parents have the task of helping their children succeed by helping them learn how to use it. According to Bradley and Corwyn (2006) when parents engage their children in academic activities it supports the connections children make with school and with their teachers. Research from several different countries demonstrates that the level of children's number skills when they enter school predicts later success not only in mathematics but also other academic subjects (Aunio, Aubrey, Godfrey, Pan, & Liu, 2008; Aunio & Niemivirta, 2010; Duncan et al., 2007; Krajewski & Schneider, 2009; National Mathematics Advisory Panel, 2008). This means what happens in the early years in the home environment is especially relevant.

Several studies (e.g., Huntsinger et al., 1997, 2000; Lefevre et al., 2002; LeFevre et al., 2010; Pan et al., 2006) demonstrated that parents from various cultures define differently their involvement in teaching their children mathematics. For example, Chinese and Chinese-American parents emphasized teaching their children math more than Euro-American parents (Huntsinger et al., 2000; Pan et al., 2006). Greek parents engaged in numeracy activities less frequently than Canadian parents (LeFevre et al., 2010). Within the Canadian culture, French-speaking parents reported fewer number teaching activities than English-speaking parents. In each case the researchers pointed to differences in the value that the respective cultures placed on children learning math, which then corresponded to the variations in frequency and emphasis.

Research comparing different income groups can also highlight both the similar and dissimilar ways parents approach the task of social integration. Observations of parents from low- and middle-income groups (e.g., Ramani et al., 2015; Saxe et al., 1987; Vandermaas-Peeler & Pittard, 2014) indicate that parents in both groups adjust their teaching to the needs or interests of the child. However, some

studies report differences in teaching strategies or the frequency of parent–child interactions about math among in different income groups (Benigno & Ellis, 2008; Saxe et al., 1987; Vandermaas-Peeler et al., 2009) others do not (Missall et al., 2015; Tudge & Doucet, 2004).

When parents belong to a group (cultural, socioeconomic, etc.) that places value on math, membership in this social network may help define their goals for their children. Often language differences are the primary way that cultural differences have been studied but other aspects of the culture may be as important (Cankaya, LeFevre, & Dunbar, 2014; LeFevre et al., 2002). DeFlorio and Beliakoff (2015) compared the home numeracy environments of children from low- and middle-income backgrounds and found few differences in the frequency of reported numeracy activities but more differences in parental expectations. Parents from middle-SES backgrounds had higher expectations. They also appear to provide a more supportive numeracy environment than parents from low-income backgrounds (Starkey & Klein, 2008). And yet, Ramani et al. (2015) found wide variation in home numeracy activities and math language in the homes of preschool children from low-income backgrounds. An interview study by Cannon and Ginsburg (2008) illustrates the interconnected, contradictory, and complex nature of how parents see the role of math in their children’s environment. They interviewed White and Latina mothers of preschool children from low-, middle-, and high-income backgrounds about the role of math in their child’s home environment and found relatively few differences connected to background. Mothers reported that they thought that math should be learned during a child’s daily activities and reported engaging in some of these activities, but they had no goals for their child’s math learning and thought math was less important for their children to learn than other skills.

Studies such as these indicate that we need to continue to include comparisons both within and across different cultural and income groups if we are to fully understand how parents approach the task of social integration with respect to mathematics. Including children’s mathematical development as a variable is also important in order to identify patterns in the fit between parents’ behaviors and attitudes and children’s level of development and to identify changes that take place in parents’ behaviors and attitudes as children develop.

Future Challenges

One of the thorny issues facing those who study the effects of the home numeracy environment is making comparisons across studies given the diverse methods used to measure the home numeracy environment. This variation could explain the inconsistency in results. While some researchers have reported correlations between measures of the frequency of home numeracy activities and children’s performance (e.g., Kleemans et al., 2012; Pan et al., 2006; Skwarchuk, 2009; Skwarchuk et al., 2014) others have not (Blevins-Knabe et al., 2000; DeFlorio & Beliakoff, 2015; LeFevre et al., 2009; Missall et al., 2015). Tudge and Doucet (2004) argue that

many studies lack information about what happens in everyday life and that parental reports are limited. Parents may not know all that happens in the home or think some activities are unimportant. LeFevre et al. (2009) and Manolitsis et al. (2013) indicate that social desirability might influence parents' reports. Skwarchuk et al. (2014) have reported some promising work on a parental report measure.

Much work remains before there is a common measure of home numeracy. Bradley (2000), after years of developing measures of the home environment, outlines the difficulties of measuring the home environment. He argues that when we are searching for "cause" indicators (Bollen & Bauldry, 2011), it can be difficult to find and include all of those that are relevant. In the case of home numeracy, cause indicators are those that influence the mathematical development of children. Omission of relevant cause indicators means that we may paint an inaccurate picture of the theories that influence home numeracy environment. Bradley (2000) suggests continuing to experiment by adding new indicators in order to counteract the effect of possible omissions. We need to keep experimenting with indicators that have different levels of focus in order to achieve the deepest understanding of the home environment.

The home numeracy area is in a relatively strong position with respect to future work on these issues. Skwarchuk et al. (2014) used previous work in the home literacy area as a guide to identifying home numeracy indicators. Active research is occurring in many countries with children from a variety of backgrounds. Multiple measures of both the home numeracy environment and children's performance are used across studies. This very diversity in measures can undermine comparisons across studies and yet it facilitates the identification of a broad range of relevant indicators. There is a strong possibility that measures of the home environment that are not specific to mathematics will be as influential, if not more so, than measures that are more specific. When the field reaches the point that results are more consistent and robust we will know the set of indicators is strong.

Concomitantly, more longitudinal research is needed to address questions regarding findings such as the negative correlations between the frequency of home numeracy activities and children's mathematical performance (Blevins-Knabe & Musun-Miller, 1996; LeFevre et al., 2009; Skwarchuk, 2009). The post hoc explanation that parents provide more help to children who are having trouble is only one of several possible explanations. Alternatively, a low frequency of home numeracy activities could mean that the activities are not a match for the child's developmental level. Higher frequency levels could indicate a developmental match and a time of maximum learning. During this time children may find some of the activities that are a developmental match more challenging than others and perform more erratically as they master them. When the parent is factored into the interaction, low frequency levels of home numeracy activities could mean that the parent is not engaged in the activity due to lack of interest, or knowledge, on the part of either the parent or child. Understanding these issues could serve as the basis for understanding individual differences and how large a role the home numeracy environment plays in the mathematical development of young children. While there are some longitudinal studies (e.g., Anders et al., 2012; Skwarchuk et al., 2014) more are needed to track changes in the different types of mathematical skills that develop in the early years

with the corresponding changes in the types and frequencies of home numeracy activities. The effects of the home environment are likely to be cumulative (Bradley & Corwyn, 2004) and longitudinal studies can test this prediction.

Conclusions

Hannula-Sormunen, Lehtinen, and Räsänen (2015) have identified spontaneous focusing on numerosity as an early indicator of later success in mathematical performance in school. We do not yet know why some children are more likely to focus on numerosity than others. It is reasonable to predict that the home numeracy environment has a role to play. As research on the home numeracy environment continues, more indicators will be included in models addressing the effects of the home numeracy environment which may allow us to address questions such as the one earlier. There are multiple ways that parents regulate children's home numeracy environments. Parents provide access to stimulating materials, engage children in math activities, and tailor their instruction to the developmental level of their children (e.g., Benigno & Ellis, 2004; Lukie et al., 2014; Vandermaas-Peeler, Boomgarden, et al., 2012). If they are skillful, parents provide an environment that fits with the child's needs. Bradley and Corwyn (2004) provide a conceptual framework that facilitates hypothesizing about the role of parents and redirects the focus from parent characteristics (demographic, attitudes, beliefs) to the goals that direct their behaviors. If this new focus can be harnessed to meta-level theorizing about the home numeracy environment, we may be able to identify and measure indicators that influence how children seek and learn the math in their environments. We may also then be able to answer questions such as whether there are core features of the home environment that influence all types of cognitive development, including mathematical development, and, whether there are features of the home environment that have a unique relationships to mathematical development.

In sum, embracing a systems-oriented approach, as suggested by Bradley and Corwyn (2004), will allow researchers to adopt a more holistic view of the relationship between the home environment and children's mathematical development. This broader view allows researchers to expand their model to include multiple variables (i.e., physical materials, socioemotional support, stimulation) and discover more about the paths between them.

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