

Development of a Game-Based Mathematics Curriculum for Preschool

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Abstract: America's deficiency in mathematics can be benefitted by an emphasis in mathematics from an early age. An effective math curriculum for preschool should consist of the most important aspects of early childhood mathematics, including number writing and identification, one-to-one correspondence, cardinality, number comparison, ordinality, number sequence, and number bonds.

Since Sputnik was launched into orbit in 1957, the United States commenced the Space Race and promoted a general emphasis on mathematics and science. This was, at least, very short-lived (Bybee, 2007). Some even argue that although many efforts are being made to reform education in the United States, there has been no substantial evidence that our students are learning more or that our society is any better (Bunting, 1999, p. 213). In other words, this reform has been deemed by some to be ineffective.

The Bush administration (2000-2008) has made an effort to address the call for educational reform by implementing the No Child Left Behind Act (NCLB). This has ultimately led to a system based upon prescribed teaching to meet the expectations of high stakes testing (Guisbond & Neill, 2004). The "narrow scope" of the standardized tests was summarily imposed by this law. The strong sanctions attached to it induced teachers to participate in "teaching to the test," which is said to undermine reform efforts (Guisbond & Neill, 2004, p. 13). Moreover, scholars argue that the framework of NCLB has not done much to remedy the problems and challenges faced in American education in all areas, including mathematics.

Mathematics underachievement in American education has far-reaching effects that may adversely affect the national economy and subsequently society at large if no viable solution is sought. Research conducted by The National Research Council (2007) on this matter has noted that the state of America as an international competitor on a level economic and technological playing field is one of "quiet crisis" (p. 25), brought on directly by an insufficiency of achievement in the fields of mathematics and the sciences. The authors argue that education in America is full of problems that require a long-term commitment from educational policymakers. They believe that the issues in American education are slowly spiraling and should not remain unaddressed until the bubble bursts. In order to prevent this from happening, the public education system must lay the foundation for developing future workers who are literate in mathematics and science, as well as other subjects. Such an approach should be implemented immediately in order to deter the imminent effects of generations well into adulthood that have suffered through a deficient educational system.

Addressing this problem would help the United States maintain its competitive edge in technology and industry on an international scale. The authors of *Rising Above the Gathering Storm* write that for now, the United States is still the leading worldwide competitor in the performance of basic and applied research, but if the educational system in America continues to decay as it has until recently because of the problems in mathematics education, this may not be the case much longer, since many of our researchers are imported from other countries and other nations are emulating the American system of research to attract and develop their own scientific minds (National Research Council, 2007). This brings the competition to a new level, since the

Hernandez, G. (2013). Development of a game-based mathematics curriculum for preschool. In M. S. Plakhotnik & S. M. Nielsen (Eds.), *Proceedings of the 12th Annual South Florida Education Research Conference* (pp. 110-115). Miami: Florida International University. Retrieved from http://education.fiu.edu/research_conference/

United States will cease to be the only dominant innovator, and the playing field will become leveled. If this becomes the case, and there are already visible signs of this occurring, America may actually be at a disadvantage, since it lacks the educational infrastructure to foster the types of mathematical and scientific thinking in its own constituents to overcome the gap of the expanding field.

To address these needs, it is important to start from an early age. As with many educational issues, early intervention is the key to success, and produces results with more long-term impacts, as can be seen in the example of the Head Start program (Deming, 2009). Young children are capable of learning substantial mathematics, but too many of them begin from a disadvantaged point and progress in the wrong direction in this discipline (Clements & Sarama, 2011). Interventions in mathematics education for children aged 3 to 5 have a strong positive effect not only in their immediate context, but many years later (Clements & Sarama, 2011). For this reason, preschool is deemed an adequate age to intervene and implement such a curriculum that could give disadvantaged students a key lead in their education.

Mathematics has long been considered a towering educational obstacle, before which many students crumble in fear and despair. This may be due to an inadequate foundational structure in mathematics from an early age, which in turn affects student motivation with respect to the subject. In a Belgian study, characteristics of the learning environment, such as the extent to which the teacher motivates students to learn mathematics, were positively correlated with student enjoyment of mathematics (Vandecandelaere, Speybroeck, Vanlaar, De Fraine, & Van Damme, 2012). Another study found a positive correlation between mathematics attitude, academic motivation, and mathematics achievement (Moenikia & Zahed-Babelan, 2010). Games can provide students with motivation and arm them with a positive disposition toward mathematics, which can help increase their academic achievement in this subject area.

Purpose

Given this, the purpose of this research is to suggest the development of a game-based mathematics curriculum for preschool that will effectively move children from a counting principle to a number principle, as based on research by Chi, Slotta, and de Leeuw (1994). A counting principle limits children to very concrete mathematical experiences based on sets they can see, and often inaccurate representations of numerical magnitudes. On the other hand, when children move towards a number principle, they carry out more abstract functions with numbers because they have an internalized notion of numbers and their meanings. It becomes possible for them to reason about numbers and more readily perform more elaborate calculations with them. Overall, it helps them to lay a great foundation in mathematics that they can carry with them throughout the rest of their education.

The development of game-based preschool mathematics curriculum on the basis of one-on-one interventions is proposed. Such a curriculum should focus on ways to reach not only regular preschool students, but also those who are at risk for low performing because of the achievement gap and the gender gap associated with mathematics. It must develop their number sense and other important early math attributes. It is expected that the students who participate in such a program would not only benefit from it academically, but will also develop a love of learning in the area of mathematics, as well as an acute awareness of mathematical concepts in their immediate environment.

Significance

The significance of this study is multifold. The implementation of an effective game-based preschool mathematics curriculum could have a large impact on student motivation and

acceptance toward learning mathematics. It also serves to lay a strong foundation in mathematics, which will serve as a scaffold for further learning in this area. This should be a goal of any education in early childhood. Early intervention has been found to have positive effects on children at an international level (Nores & Barnett, 2010), which means that this is an intrinsically human feature, not tied to any particular race or culture. Since this curriculum is designed for young children, it maintains the same properties of early intervention studies, which tend to have a greater positive effect than interventions performed at an older age.

Targeting students from a low socioeconomic background would have implications for helping to bridge the achievement gap (Tucker-Drob, 2012), which is one of the aims of legislations such as the NCLB. If the proposed curriculum is successfully implemented, it can help raise the standards of American education in general because it would help the lowest achievers to become better-achieving.

The implications of the implementation of a curriculum like this should be widespread. It is important for this problem to be addressed as soon as possible, since the long-term societal effects of these interventions tend to be cascading and do not show positive effects, except for the immediate classroom ones, until years later.

Framework for the Curriculum

The proposed game-based preschool math curriculum is designed to be both age-appropriate and teacher-friendly, which is more likely to ensure its implementation. Support for game-based mathematics curricula can be found in numerous studies. The topic has been trending in the past decade. Games as simple as Chutes and Ladders have an enormous impact on the way young children comprehend mathematical concepts (Cavanaugh, 2008). This is even more so when they play games designed to foster development of specific areas of mathematical understanding according to their age and developmental stage.

An effective math curriculum for this age group must be fairly comprehensive, and should consist of the most important aspects of early childhood mathematics, including number writing and identification, one-to-one correspondence, cardinality, number comparison, ordinality, number sequence, and number bonds. These concepts are all interrelated and cannot easily be distinguished from each other, but together, they all make up the important conceptual and procedural framework for learning mathematics in the preschool age. They have been grouped into five cohesive categories that correspond to strands of standards from several different organizations, including the National Association for the Education of Young Children (NAEYC), the National Council of Teachers of Mathematics (NCTM), and the Florida School Readiness Performance Standards for 3 and 4 years old children. These five components and their importance are described in further detail as follows.

Number Writing and Identification

Number identification is one of the most crucial tasks that young children must learn to establish early numeracy. As a matter of fact, number identification is commonly found as a curriculum-based assessment measure of early numeracy, and there is a relatively high validity for this measure with respect to essential math skills, such as number sense (Lee, Lembke, Moore, Ginsburg & Pappas, 2012). Given this, number writing is considered an important aspect of early mathematics learning that helps children learn to identify the numbers. However, the task of number writing goes beyond simple number identification, but also influences their concept of number. A study by Zhou and Wang (2004) comparing Chinese and English children's early conceptualizations of number found that "children's ability to represent written number symbols closely relates to their cardinal concept" (p. 253). Number writing is one of the

most elementary tasks in any preschool curriculum, but its importance cannot be undermined. When it is assigned purposefully, it can be very beneficial to the development of young children's mathematical abilities.

One-to-One Correspondence, Cardinality, and Ordinality

One-to-one correspondence is an integral component of early mathematics education. As a principle, it states that one number-word corresponds to only one object. This principle was identified by Gelman and Gallistel in 1978 and, although it is in opposition to Piaget's theory early mathematics with respect to number conservation, the concept of one-to-one correspondence has been shown to be implicit in children's ability to learn to count, and has laid the foundation for preschool mathematics work since then (Sophian, 1988). This principle, in combination with some of the other ones mentioned, is a key for young children to learn to count and establish cardinality.

Cardinality is an extremely important concept that is critical to establish in the minds of young children. In fact, the first impression that comes to mind when thinking about young children's conception of numbers, counting, and early mathematics is tied to the concept of cardinality. Cardinality refers to the amount of items in a set. Although seemingly simple, this concept is actually quite complex in the minds of children aged three to five. It not only involves attaching the quantity to the last number-word corresponding to a given set, but also works together with one-to-one correspondence to ensure that the last number-word is representative of the actual amount represented (Bermejo, Morales & Garcia deOsuna, 2004). With time and practice, children can move through the set of stages described by Bermejo et al. (2004) to achieve an accurate conception of cardinality through counting.

Ordinality, as the name implies, refers to the "operational understanding and significance of ordering, the principle of a numerical reference to position" (Bruce & Threlfall, 2004, p. 7). Ordinality as a principle of early understanding of numbers does not limit itself to learning the ordinal number names. In fact, Piaget's work on ordinality supports the notion that children acquire an understanding of the ordinal aspect of number without knowledge of the ordinal names. However, other studies have shown that the use of ordinal names is great aid in helping children understand the concept of ordinality (Bruce & Threlfall, 2004). Ordinality plays an influential role in the development early concepts of number.

Number Comparison

Number comparison in early childhood math is important because it helps to establish an understanding of numerical magnitudes. Number comparison is the means by which children understand how big a number is in comparison to another. A solid understanding of numerical magnitudes may lead to improved performance on other numerical tasks (Sophian, 1988). Interestingly, number line comparison studies among kindergarteners have found that they tend to exaggerate differences among smaller numbers and compress differences among larger ones. This appears to be a developmental trait since they no longer tend to do this in second grade (Laski & Siegler, 2007). In order to aid in the proper development of this skill, it is essential to provide practice in appropriate activities to foster its advancement, since it is a skill that is important to the overall development of the concept of number.

Number Sequence

Number sequence is related to the concept of ordinality in the sense that it deals with the order of the number-words used, but not in a positional manner. Here, it refers most importantly to a type of mathematical skill often called "counting on." The skill of counting on is considered the best predictor of performance on other numerical tests and plays a key role in the

development of children's arithmetic performance (Johansson, 2005). Providing children practice with number sequence tasks is fundamental to the movement from a counting principle to a number principle.

Number Bonds

Number bonds refer to known combinations of numbers that occur frequently. This is part of what is more broadly termed "number sense." For example, when a child intuitively knows that two and two make four, this is a number bond that he/she has learned. Children can develop algorithms based around known number bonds to achieve understanding of different problems (Tall, 1978). Knowledge of number bonds comes from dealing with numbers and their bonds to develop a rule of thumb. This is a more advanced task that helps move children closer to a number principle because it is based on abstraction. Mastery of number bonds would signify making the shift towards a number principle.

Conclusion

The implementation of a preschool curriculum that includes all of these core aspects of early mathematics promises to produce great results and be very beneficial to American mathematical education overall. Since it would lay such an extensive foundation in mathematics, extending towards all the basic areas that make up the conception of number in young children, it would promise later success in mathematics education as well, hopefully producing a new generation of learners that do not suffer the hindrances of the current one and giving America a more competitive edge on a global scale.

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