Learning Linearly: Preschoolers' Concepts of Math Through Board Games
Interpretation Guide

Background:
Children have a natural interest in math, and math is a part of their everyday play. This can be seen when children play with blocks: "My tower is taller than yours!" or when they role play: "I need to bake five cookies so we all can get one for dessert." Children especially use math ideas during board games: "I need two spaces to win!" They are constantly building on their knowledge of concepts like counting, understanding magnitudes, and estimation. Of particular importance is their development of a linear representation of number, as it is utilized every day in arithmetic, decimals, and discriminating among magnitudes of larger numbers (Whyte & Bull, 2008).

Studies in early childhood math are fairly recent, as many preschool and kindergarten classrooms focus primarily on literacy and social development, and not on science, technology, mathematics and engineering (STEM). Legislation is now being pushed that provides for the essentials of early math skills to be taught at school. It was originally believed that any math experience this early was developmentally inappropriate, but we now know that this is not the case. Children have an extraordinary ability to learn math—*but* this learning is best when there is greater transparency of mapping between the math-related toys they play with, and the desired internal representations. This is formally known as the "representational mapping hypothesis." In short, it is most effective when a game's math-related goals and features are salient.

This study uses the representational mapping hypothesis to look at how children learn counting, magnitude (comparing values of numbers), and numerical estimation on number lines (being able to accurately place an integer on a number line between two values). Interventions of three different math games were used here—a "nonlinear number group, linear color group, and linear number group" (Whyte & Bull, 2008). The board game here at the Bay Area Discovery

Museum is modeled after the "linear number group" intervention, in which children spun a spinner and moved that number of linear spaces while counting aloud the numbers they passed. This intervention was meant to have the clearest mapping between the physical game itself and the goal of the game—to support the child's understanding of linearity and numerical estimation on number lines.

Researchers found:

- ❏ Both the nonlinear game group and the linear number board game group showed improvements from pre-test to post-test in counting and magnitude, which are basic numeracy skills.
- ❏ Only in the **linear number board game group** did the children's **number line representations** improve.
- ❏ The linear number board game had multiple *correlated cues* to numerical magnitude: the number on the spinner corresponding to the distance moved on the board, the greater number of moves corresponding to more time needed, and the greater number of count words used overall in the game—under the representational mapping hypothesis, these cues make it the best format for a board game intended to support children's understanding of numerical magnitude as linearly increasing.

Why is this important?

Children's early math skills are highly related to their later performance in both math and reading through third grade (Booth & Siegler, 2006; Siegler & Booth, 2004). Playing the linear math board game for a few weeks improved children's understanding of linear representation, which in turn facilitates learning of estimation on number lines. This skill has been found to be significantly correlated with improvements in arithmetic abilities and achievement scores. In education, there is increasing recognition of the importance of early STEM experiences, aligned with one of the Bay Area Discovery Museum's missions.

Method:

Recruiting Methods:

Introduce yourself to parents, explaining to them that you are demonstrating a study at the Bay Area Discovery Museum that looks at how young children learn math. Ask if their child would like to play a fun board game with a spinner.

Activity Instructions (the "study method")

Please reference the procedure for the "Linear Number Group" of the original study (Whyte & Bull, 2008)

1. –if child is 2-4, use the 1-10 board, if child is 5 and up, attach the 11-40 section—
2. Place the board game on the table and introduce child to the toy ("This is a fun board game I like to play with my friends. It has numbers on it, and we get to both start here! (point to the 1 space). Which piece do you want to be?" –let them choose).
3. Place both player pieces on the 1 space. "The goal of this game is to get to the Golden Gate Bridge first!"

4. “There are a few rules are you ready? First you need to spin this spinner (spin it so they see), *then* you need to move your piece however many spaces the number you got on the spinner says.” –“But there’s another special rule. When you go over a space on the board, you have to say whatever that number is out loud” (demonstrate).
5. Have them go first, and then you take a turn. Do so until game is complete.
6. “Awesome job!!! Okay, so now I have one more thing I want you to try.” Place number line in front of child (0 on left and 10 on right). Give them digit to hold. “I want you to put this number on the number line where you think it goes…..Great job!” ……
7. Talk with the child’s parent about what the original researchers were studying, and about what the results the researchers found.

Activity Tips (e.g., what to observe as the child plays, discussions to have with parents)

Help parents observe:

· How many count words are used during the play of this game?

· Do children try to count just the amount of spaces they spun rather than the numbers they are passing?

· Have you seen board games like this at the toy store or at school? What types of other math games have you seen? What skills do you think they were trying to support?

Keeping kids interested:

· Draw the child’s attention to the spinner (ooh fun!) and the aesthetic of the board game (traveling to the Golden Gate Bridge).

· Move more quickly through the board game (especially on your turn).

· Ask older children to guess what number they will land on after they spin but before they move their player piece.

Results of the Original Study

- ❏ Children who repeatedly played a game like this one, as opposed to a board game with a different shape, or that emphasized color words, showed greater improvements in linear representation (69% pretest to 100% posttest) when they were asked to place a number on a number line.
- ❏ Both groups who played a game relating to number improved more on their counting and magnitude skills compared to the group that played a color game. This shows that these important skills can be supported by math-related activities on the parents’ part, and that regardless of the game format, there is value in practicing number words with children, and engaging them in early math activities.

Questions Parents May Ask:

What age does my child have to be in order to participate?

The original study had 3-4 year olds participate. However, since this is just a demonstration of the study, children of any age are welcome to participate.

Did my child "pass"?
There is no right or wrong way to play the board game and extremely variable results across age groups. This game in the original study was used as an intervention, that was played over multiple weeks with children to look at its impact on their development of early math skills. This demonstration is just to show you what we do in developmental psychology research.

What is the average age that children are able to place numbers correctly on a number line?
Children begin counting very early on, and begin placing numbers correctly on number lines during preschool. As the numbers get larger (1-100 instead of 1-10), the placement becomes harder to get right, even in adults.

Where can I get more information on the study?
Give parents the hand-out flyer.
http://www.parentingscience.com/preschool-board-game-math.html
Visit the National Association for the Education of Young Children (NAEYC) website for families:
http://families.naeyc.org/
and their position statement on mathematics:
https://www.naeyc.org/files/naeyc/file/positions/psmath.pdf

Activities for Parents to Try at the Museum:

- ❏ Try out the nation's first early childhood Fab Lab, engaging STEM skills through hands on learning of bringing your child's ideas to life
- ❏ Explore the museum using the "Math in Motion" Creativity Kit
    - ❏ *Check the calendar on the BADM website for days and times!*
- ❏ In Bay Hall, encourage your child to use number words while fishing! How many fish did they catch? Ask how they can move the blocks in the Port of Oakland section to help develop spatial understanding. Or, play at Fisherman's Wharf by buying some seafood and use number words in relation to money!
- ❏ Let your child guide their own play in Imagination Playground! The giant foam blue blocks are used to build anything your child can think of that will stay standing—which is important for creativity and early math learning! Compare the sizes of different blocks or have your child estimate how many blocks they used in their structure.
- ❏ Check out the STEM Superheroes Series
    - ❏ *Saturday, May 14: Code Our Future: Super Solving with Robots*

Activities for Parents to Try at Home:

- ❏ Play games like Chutes and Ladders, or even make your own linear number board game like the one we used today! http://www.parentingscience.com/preschool-math-games.html
    - ❏ Children do best when exposed to board games in a frequent manner and in a variety of settings--school, home, museum, friend's house, etc.
- ❏ **Use number words in everyday speech very often, pointing out objects by counting them, comparing sizes of objects, estimating values, etc.**

- ❏ Play with numbers! You could try paint-by-number for an art activity! Support their numerosity (counting abilities), 1-1 correspondence (knowledge that a number corresponds to one thing when counting), and cardinality (understanding that the last number counted in a set of objects represents how many total objects there are). A fun way to incorporate cardinality could be to have your child count their stuffed animals—or something they collect—and ask how many are in their room!
- ❏ Calendars and rulers are awesome things to take advantage of—they have linear numbers!!!
- ❏ Measure your child's height to show them how much they've grown
- ❏ Sing songs like "One, Two, Buckle My Shoe" and "5 Little Monkeys Jumping on the Bed"
- ❏ For wonderful ideas: http://www.parentingscience.com/preschool-math-lessons.html

References

Booth, J. L., & Siegler, R. S. (2006). Developmental and individual differences in pure numerical estimation. *Developmental Psychology*, 41, 189 –201.

Siegler, R. S., & Booth, J. (2004). Development of numerical estimation in young children. *Child Development*, 75, 428 – 444.

Whyte, J. C., & Bull, R. (2008). Number games, magnitude representation, and basic number skills in preschoolers. *Developmental Psychology*, 44(2), 588-596.