We propose an Early Math Trajectory Model that is predictive of later mathematics achievement for children from low-income backgrounds. We evaluated the Early Math Trajectories model within a longitudinal study of over 500 children from age 4 to 11.

### Background
Mathematics knowledge begins to develop at a young age, and this early knowledge predicts later math and reading achievement (Duncan et al., 2007; Watts et al., 2014). We propose an Early Math Trajectory Model that encompasses a set of six early math topics that evidence indicates should be of particular importance for supporting mathematics achievement in the middle grades (See Figman, The 6 topics are:

1. **Nonsymbolic quantity:** Magnitude of sets, without need to use symbols (LaFevre et al., 2010; Libertus et al., 2013). E.g., "Which one has more?" 3 vs. 4 dots.
2. **Counting:** Counting objects, including cardinality (Aunola, et al., 2004). E.g., "Count 5 cans and tell how many.
3. **Symbolic Mapping:** Mapping between symbolic numerals, number names and magnitudes (Kolkman et al., 2013; Sasanquale et al., 2012). E.g., "Match numerals 1-5 to the number of grapes."
4. **Calculation:** Calculating combination or separation of sets (Geary, 2011). E.g., "Here are three pears. How many are there in all?"
5. **Patterning:** Finding a predictable sequence in repeating patterns (Papic et al., 2011). E.g., "Finish my pattern here" when shown ABAB patterns.
6. **Shape:** Identifying shapes and their properties (Clements & Sarama, 2009). Included based on theory rather than evidence. E.g., "Select all the triangles" from a collection of 24 shapes.

### Current Study
Participants: 919 students from low-income homes, originally recruited from pre-K classrooms and participating in the Peabody Research Institute Middle School Follow Up Project (55% female; 75% Black, 9% Caucasian). Data collected at beginning and end of pre-K (Age = 4.4 and 5.0 years, respectively), end of first grade (M = 7.0 yrs) and end of fifth grade (M = 11.0 yrs) though 14% had been retained in 4th grade.

**Early Predictor Measures:**
- Research-based Early Maths Assessment (REMA; Clements, Sarama & Liu, 2008). Numeracy items were broken into four subscales, in line with past research (Purpura & Lonigan, 2013). Patterning and shape items were treated as separate subscales.
- General cognitive and academic skills were assessed, including narrative recall skills (using the Renfrew Bus Story or Woodcock Johnson III Story recall, depending on time point), reading skill (using WJ Letter-Word Identification), and teacher ratings of work-related skills (Cooper-Farran) and self-regulation (from Instrumental Competence Scale for Young Children-Short Form).

**Age 11 Mathematics Achievement Measures:**
- Composite math achievement on norm-referenced measures: Sum z-scores on 3 KeyMath Diagnostic Assessment subs (Numeration, Algebra, and WJ Quantitative Concept subtest; individually administered).
- State test scores on the Tennessee Comprehensive Assessment Program (TCAP).

**Results**
In preschool, individual differences in nonsymbolic quantity, counting and patterning knowledge predicted fifth-grade mathematics achievement over and above many other math and cognitive skills, with a few exceptions (see Table 1). In first grade, individual differences in symbolic mapping, calculation and sometimes patterning knowledge were key predictors of later math achievement; shape knowledge was not (see Table 1). In addition, nonsymbolic knowledge was a predictor of state test scores.

### Conclusion
Strong support for Early Math Trajectories model for low-income children. Early patterning knowledge merits increased attention in theories of math development and should be included in early standards (contrary to Common Core State Standards, 2010).

Non-symbolic quantity knowledge in preschool may have an indirect effect on later achievement (see DeSmedt et al., 2013). It may support several primary-grade math topics, including symbolic mapping, calculation and patterning knowledge.

We will follow children through age 14 and evaluate whether these relations are consistent at later grade levels.