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Validation of a brief, screening measure of low-income pre-kindergarteners' science and engineering knowledge

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ABSTRACT

Despite their importance for developing higher-level reasoning and communication skills, science and engineering represent domains that are often untaught and untested in pre-kindergarten (Evangelou et al., 2010; Greenfield et al., 2009). Science assessment is not common, in part, because measures of young children's scientific knowledge are not currently available for at-scale use. In a sample of 327 children (mean age 4.45 years) from predominately low-income backgrounds, we examined the psychometric properties of a new screening measure of young children's science and engineering knowledge. We present findings regarding test-retest reliability, internal consistency, construct validity, and concurrent validity of the new measure. Results indicate adequate psychometric properties across examined areas for the new measure, including strong concurrent correlation ($r = .80$) with a standardized diagnostic science measure, the Preschool Science Assessment (Greenfield et al., 2014). However, both science measures were moderately correlated with children's general vocabulary knowledge ($r = .65–.70$), indicating overlap between these constructs. Discussion focuses on the importance of measuring young children's science and engineering knowledge as a first step toward increasing teachers' awareness of these high-priority instructional domains.

Reforming science education has become a high priority in the United States for many reasons (Griffith and Cahill, 2009; National Center on Education and the Economy, 2006; National Research Council, 2012). First, the majority of 4th graders (66%) are not proficient in national science expectations (National Center for Education Statistics, 2011). Second, international comparisons show that the U.S. lags behind other industrialized nations in science achievement (Buckley, 2012). Third, despite increasing global demand, decreasing numbers of U.S. students pursue science-related degrees and careers, with particular shortages among women and minorities (Buckley, 2012; Burke & Mattis, 2007).

These disappointing national trends in science and engineering achievement and careers prompted recent standards-based movements to increase K-12 expectations for science and engineering instruction that is cohesive across grades and that requires greater in-depth study of a more limited number of core ideas (Next Generation Science Standards, 2013; National Research Council [NRC], 2012). For example, 26 states participated in a three-year process to develop the K-12 Next Generation Science Standards (Next Generation Science Standards, 2013) that are designed to mirror the more rigorous expectations for reading and math found in the Common Core State Standards in the domains of science and engineering practices. Since the 2013 release, 12 states have gradually adopted the NGSS standards, to date (Heitin, 2014). But few national efforts have focused on science and engineering standards for preschool and some states do not yet have separate science standards for preschool (Greenfield et al., 2009; Saçkes, Trundle, & Flevares, 2009).

Some reform approaches use data to increase expectations and illuminate instructional needs in typically untested grades and subjects (Bornfreund, 2013). Preschool teachers rarely assess science and engineering knowledge (Brenneman, 2011), making this an important area to increase awareness and expectations. This paper describes the validation of a new measure designed to screen young children's science and engineering knowledge that can be readily administered by classroom teachers. The next sections explain the need for such a measure based on the limited ways in which science and engineering are currently taught and assessed in the preschool years.

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1. Science & engineering instruction in early childhood

Young children are capable of higher-level reasoning than previously understood (Bonawitz, Horowitz, Ferranti, & Schulz, 2009; Sobel and Kirkham, 2006), thereby highlighting early childhood as a critical period for introducing the sophisticated reasoning surrounding science and engineering (Bagiati, Yoon, Evangelou, Ngambeki, 2010; Brenneman and Louro, 2008; Gelman & Brenneman, 2004; Greenfield et al., 2009). Exposing young children to science and engineering topics is theorized to capitalize on their curiosity about the surrounding world while providing a foundation for future scientific learning in school (Brenneman, Stevenson-Boyd, & Frede, 2009; Conezio and French, 2002). It is not clear from the limited research to date whether early science learning opportunities longitudinally predict children's science achievement (Saçkes, Trundle, Bell, & O'Connell, 2011), but early exposure to science is associated with positive attitudes toward science in later grades (Bruce, Bruce, Conrad, & Huang, 1997; Eshach and Fried, 2005).

Current evidence suggests high-quality science and engineering instruction for young children: (a) addresses content knowledge alongside process skills, and (b) uses inquiry-based methods. More specifically, science frameworks address both the "what" and the "how," corresponding to disciplines/content knowledge and scientific inquiry/process, respectively. The four domain-specific *disciplines/content areas* include: physical sciences, life sciences, earth and space sciences, and engineering design (National Research Council, 2012). *Process skills* include the collective inquiry activities scientists and engineers use such as: asking questions, carrying out investigations, reasoning about data, and theory building (National Research Council, 2012). Although science and engineering are closely related, engineering is a unique discipline that applies mathematical and scientific concepts to real-world problems with iterative tests to optimize design solutions (Bers and Portsmore, 2005). The current "gold standard" in science and engineering is *inquiry-based instruction* that starts with a question and then uses guided, hands-on investigations to address cross-cutting themes such as patterns, cause and effect, or stability and change (Gelman and Brenneman, 2004; Gerde, Schachter, & Wasik, 2013; National Research Council, 2012; Trundle & Saçkes, 2012). Such instruction is theorized to promote domain-general skills, such as higher-level reasoning, learning strategies, and advanced communication skills, which may support learning in content areas beyond science (Brenneman et al., 2009; French, 2004; Peterson and French, 2008).

Yet most research shows little effective instruction is devoted to science and engineering topics within early childhood classrooms (Greenfield et al., 2009; Nayfeld, Brenneman, & Gelman, 2011; Saçkes, Trundle, & Bell, 2013; Tu, 2006). Most estimates indicate only 7% to 13% of the school day focuses on science (Connor, Morrison, & Slominski, 2006; Early et al., 2010; La Paro et al., 2009; Tu, 2006), although broader definitions that include informal science instruction can be as high as 26% of instructional time (Piasta, Pelatti, & Miller, 2013). Even less established in early childhood is the domain of engineering instruction (Evangelou, Dobb-Oates, Bagiati, Lian, & Choi, 2010; Katehi, Pearson, & Feder, 2009). Preschool teachers often report that they feel unprepared to teach science and engineering compared to other areas, such as language and literacy, and report difficulty finding time to teach science (Greenfield et al., 2009; Yoon & Onchwari, 2006). This is perhaps due to misconceptions that science is difficult to teach and that it requires mostly memorization as opposed to hands-on exploration (Conezio and French, 2002; Yoon & Onchwari, 2006). The paucity of effective science and engineering instruction is likely also due to limited curricular resources. Innovative preschool curricular resources are gradually becoming commercially available for science (e.g., Science Start!/LiteraSci; French and Woodring, 2013; Preschool Pathways to Science; Gelman, Brenneman, Macdonald, & Roman, 2010) and engineering (e.g., robotic manipulatives, Bers and Portsmore, 2005; inclined planes/ramps, Zan and Geiken, 2010). However, these resources do not have robust evidence, to date, for the efficacy of improving child outcomes (Greenfield et al., 2009; Klahr, Zimmerman, & Jirout, 2011).

2. Science & engineering assessment in early childhood

The lack of reliable and valid assessments of preschool children's science and engineering knowledge is one of many obstacles facing current efforts to increase effective science and engineering instruction in preschool (Brenneman, 2011; Greenfield et al., 2009; Kloos et al., 2012). In fact, a 2008 review of early childhood assessments conducted by the NRC did not include any science measures, stating that such measures did not exist at the time (Snow and Van Hemel, 2008). According to a more recent review of assessments for preschool science (Brenneman, 2011), there has been limited progress in developing assessments of young children's science knowledge. Specifically, most existing classroom approaches utilize teacher observation and ratings of children's science knowledge (e.g., Galileo System for the Electronic Management of Learning; Bergan et al., 2003; Teaching Strategies Gold; Berke, Heroman, Tabors, Bickart, & Burts, 2011). However, significant discrepancies can exist between teacher ratings of child skills compared to direct, standardized assessments (Beswick, Willms, & Sloat, 2005; Hoge and Coladarci, 1989).

At present, there is only one validated, direct assessment of pre-k children's science knowledge—the Preschool Science Assessment (PSA), developed by Greenfield et al. (2014). The PSA is a diagnostic assessment that is not specific to any particular curriculum and contains an in-depth 80-item (30–40 min) flipbook assessment of children's science content knowledge and process skills using expressive and receptive items. The initial paper-pencil version of the PSA is currently in the process of being improved for use on a computer-adaptive testing platform called the Lens on Science (Greenfield and Penfield, 2013). In its current state, the PSA and the Lens on Science are used for research and evaluation purposes only. In other words, the PSA and Lens on Science are appropriately designed to evaluate a variety of science-based curricula and interventions because they are not linked to a specific curriculum; however, the PSA is not currently designed for use by teachers.

Regarding engineering knowledge and skills, to our knowledge, there are currently no early childhood assessments designed specifically to assess this domain. However, there appears to be substantial overlap between science and engineering process skills as addressed by the PSA. To summarize, the few existing assessments of young children's science knowledge are either teacher rating systems or more time-intensive, research/evaluation measures, leaving teachers with few options to directly examine children's science knowledge (Brenneman, 2011).

Direct measures of young children's science *and* engineering knowledge, designed for use by classroom teachers, are needed to monitor readiness and learning in these domains. The present study aims to fill this gap by validating a new, brief screening measure that is not linked to a specific curriculum, but is aligned with national expectations for science instruction. Screening measures are generally designed as brief measures that are administered universally to identify which students are unlikely to progress through the core curriculum adequately without additional support (Stecker, Fuchs, & Fuchs, 2008). Screening measures are usually administered by classroom teachers at the beginning and/or middle of the academic year and typically focus on domains such as language, literacy and, sometimes, mathematics (Coleman, Buysse, & Neitzel,