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# Approaches to learning and school readiness in Head Start: Applications to preschool science

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ABSTRACT

Approaches to learning are a set of domain-general skills that encompass curiosity, persistence, planning, and engagement in group learning. These skills play a key role in preschoolers' learning and predict school readiness in math and language. Preschool science is a critical domain for early education and facilitates learning across domains. However, no studies to date have examined how approaches to learning affect science outcomes in preschoolers. This study addressed this gap in the literature by testing predictive associations between approaches to learning and gains in science, as well as, math, vocabulary, and listening comprehension, across the school year, in a sample of preschoolers from low-income families. Results indicated that approaches to learning significantly predicted gains in science, and trended towards predicting gains in math, but not vocabulary or listening comprehension. These findings highlighted the potential of approaches to learning to facilitate early science learning for children from low income families.



## 1. Introduction

Upon school entry, children from low-income backgrounds lag significantly behind their higher-income peers in academic achievement (Magnuson & Duncan, 2006). This gap continues into primary school and increases over time (Ryan, Fauth, & Brooks-Gunn, 2006). Previous research has demonstrated the importance of domain-general skills, which are teachable and malleable, and facilitate learning regardless of content area (George & Greenfield, 2005). Given the documented readiness achievement gap, these skills are particularly important to identify and foster among children from low-income families (McClelland, Morrison, & Holmes, 2000).

Approaches to learning are a set of domain-general skills that have been identified by Head Start as one of the core school readiness domains (U.S. Department of Health and Human Services [U.S. DHHS], 2015). Approaches to learning skills encompass curiosity, persistence, planning, motivation, and engagement in group learning, and significantly predict school readiness in math and language among preschoolers from low-income families (McWayne, Fantuzzo, & McDermott, 2004; Schaefer & McDermott, 1999).

No study has examined the relationship between approaches to learning and preschool science, nor have any studies examined how this relationship may differ from those between approaches to learning and math, vocabulary, and listening comprehension, respectively. Preschool science is a critically important content area, which is reflected in Head Start's national recognition of science as a core school readiness domain (U.S. DHHS, 2015). Additionally, science relates to vocabulary, listening comprehension, and executive functioning (EF) skills, in preschool (Nayfeld, Fuccillo, & Greenfield, 2013). Despite these findings, science instruction is largely neglected in preschool, and preschoolers from low-income families have deficits in science readiness (Greenfield et al., 2009). Similarly, the majority of studies examining academic achievement in preschool fail to assess children's science knowledge, due to a lack of measures of preschool science (Greenfield, Dominguez, Greenberg, Fuccillo, & Maier, 2011).

Research is needed to understand how approaches to learning contribute to academic achievement, particularly in the domain of early science. This study examined if approaches to learning predicted spring school readiness outcomes (controlling for fall scores) across four distinct domains: science, math, vocabulary, and listening comprehension.

### 1.1. Approaches to learning and school readiness

Approaches to learning has received increased attention by researchers and policymakers as one of the most important school readiness domains, considering its broad impact on child development (Kagan, Moore, & Bredekamp, 1995; McDermott, Rikoon, & Fantuzzo, 2014). This set of learning styles and behaviors affects how children approach learning situations, including motivation, persistence, initiative, and a positive disposition towards learning (Kagan et al., 1995; Vitiello, Greenfield, Munis, & George, 2011). These skills have been described as

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foundational for school success, due to their malleability and positive implications for academic achievement (Schaefer & McDermott, 1999). The EPIC curriculum (Fantuzzo, Gadsden, & McDermott, 2011), which uses intentional instruction of approaches to learning as the foundation for a Head Start classroom-based intervention, provides evidence for the malleability of these skills. EPIC utilizes four evidence-based approaches to learning modules (attention control, frustration tolerance, group learning, and task approach) designed to enhance math, language, and literacy development. EPIC provides evidence of a causal link between approaches to learning and academic outcomes (i.e. math and listening comprehension). Interventions like EPIC highlight the importance of emphasizing the development of these powerful domain-general skills early to guide at-risk children towards a trajectory of academic success.

Preschool is a critical period for the development of approaches to learning, as it is one of children's earliest formal school experiences, and they are challenged each day with novel learning situations, both academically and socially (Bulotsky-Shearer, Dominguez, & Bell, 2012; Welsh, Nix, Blair, Bierman, & Nelson, 2010). During preschool, children must learn to engage and work cooperatively with peers and teachers, while remaining focused, persistent, and motivated when faced with the inevitable challenges inherent to learning. Children who demonstrate adaptive learning behaviors have greater school success throughout their academic career (Fantuzzo, Perry, & McDermott, 2004; George & Greenfield, 2005; Li-Grining, Votruba-Drzal, Maldonado-Carreno, & Haas, 2010; Matthews, Kizzie, Rowley, & Cortina, 2010; McClelland et al., 2000; McDermott et al., 2014; McWayne et al., 2004; Vitiello et al., 2011). This has been found across multiple domains of academic achievement, including math, vocabulary, and listening comprehension.

For example, McWayne et al. (2004) found that approaches to learning predicted a composite of early academic success, which assessed various indicators of child development, including literacy, numeracy, and fine and gross motor coordination in a sample of preschoolers served by Head Start. A recent longitudinal study examined children attending Head Start through 2nd grade and found that approaches to learning in the preschool years predicted proficiency in reading, vocabulary, language, math, and science in 2nd grade (McDermott et al., 2014). Some findings indicate a domain-specific effect, such that early positive learning behaviors like approaches to learning may be more important for math than language achievement (e.g. Ponitz, McClelland, Matthews, & Morrison, 2009; Vitiello, 2009; McDermott et al., 2011). Theory suggests that the complexity and unfamiliarity of math concepts requires a greater use and activation of domain-general skills (such as approaches to learning, EF, etc.), as compared to language, which children are exposed to with greater frequency throughout early development (Clements, Sarama, & Germeroth, 2016; Connor, Morrison, & Slominski, 2006; Miller, Kelly, & Zhou, 2005; NICHD Early Childcare Research Network, 2002; Ponitz et al., 2009).

### 1.2. Approaches to learning and science

Although prior studies have shown that approaches to learning predict early language and math outcomes, its relationship to science achievement in preschool has not been examined. Science is now recognized as its own school readiness domain by Head Start (U.S. DHHS, 2015), making it a crucial construct to include when measuring school readiness. Science is an interactive and engaging content area that capitalizes on young children's natural curiosity about their surrounding world. In the preschool classroom, science is evident as children explore cause and effect relationships (e.g. rolling a marble down a ramp to knock down a block), concepts such as force and gravity (e.g. pushing a ball off the table and watching it fall), and use of their senses to observe properties of objects (e.g. passing around a shell during circle time to allow children to feel the weight and texture with their hands). By going beyond rote learning and memorization, science encourages children to explore their environment and engage in science practice skills (e.g. asking questions, making predictions, conducting experiments, and recording observations) to increase their understanding of the natural world (Greenfield et al., 2009; Schweingruber, Duschl, & Shouse, 2007; U.S. DHHS, 2015).

Approaches to learning skills may help children engage effectively in scientific exploration, however, this relationship remains unexplored. McDermott et al. (2011) identified 7 components of approaches to learning that include strategic planning, effectiveness motivation, interpersonal responsiveness in learning, vocal engagement, sustained focus, acceptance of novelty and risk, and group learning. Children who display positive approaches to learning will likely navigate the scientific process more effectively. Higher levels of strategic planning, for example, are particularly useful for learning in the science domain (Urdan & Schoenfelder, 2006). Strategic planning helps children devise a thoughtful strategy before conducting an experiment. This planning ability will also allow children to set goals, plan an experiment or exploration, make predictions about what might happen and adapt their behaviors, experimentations, and explorations. Effectiveness motivation (i.e. perseverance and persistence), sustained focus in learning, and acceptance of novelty and risk equip young children with the tools to effectively deal with setbacks and failures that naturally occur during science learning and experimentation. These approaches to learning skills coalesce to aid children in effective execution of the scientific method.

For example, imagine a child who wants to build a ramp that will make a marble go fast. She can manipulate many variables, but will have to isolate them one at a time in order to identify which variable most impacts the outcome. With her teacher present to scaffold her through the process, she hypothesizes that the color of the ramp (red vs. blue) will change the speed of the marble. After testing this hypothesis she concludes that the color of the ramp does not affect the speed of the marble, leading her to revise her initial plan. She proceeds by testing if changing the slope of the ramp, by adding blocks to the base, will make her marble roll faster. After testing her second hypothesis, she concludes that a steeper slope does in fact make her marble go faster. During this process, the child demonstrated adaptive approaches to learning skills (e.g. planning, flexibility, and persistence), increased her understanding of physical science, and reached a conclusion supported by evidence. This example illustrates the importance of approaches to learning skills in the context of science learning.

Vocal engagement, another aspect of approaches to learning, helps children ask questions, verbalize frustrations, demonstrate understanding, and seek answers to problems. These are key components of inquiry, which is at the core of science learning. Children who engage in inquiry describe phenomena, ask questions, construct explanations, test them, and communicate their results to others (National Research Council, 1996). In turn, those who display more engagement in learning, via inquiry, have been shown to have better academic outcomes (Newman, 1998).

Often these information-seeking behaviors occur in social contexts within the classroom. Science activities typically occur in group settings, and children who can collaborate with peers are able to receive and provide feedback and solve problems more efficiently. Group learning and interpersonal responsiveness, the most socially-based factors of approaches to learning, lend themselves to science learning as children work together to make sense of their world. Collaboration and teamwork are integral components of science learning and children who can utilize their peers as learning resources are likely to make greater gains in their own knowledge.

In summary, approaches to learning skills may be critical for children's engagement in early science education. Given the national science achievement gap (Morgan, Farkas, Hillemeier, & Maczuga, 2016), it is important to develop domain general skills that will help children have positive experiences while learning science early in their school career. Science takes advantage of young children's natural curiosity about their immediate world and provides teachers with an engaging, interactive, hands-on, minds-on context for learning, and approaches to learning skills could help children succeed in their early science endeavors.

Prior research has found that approaches to learning predict mathematics ability more than vocabulary, listening comprehension, and alphabet knowledge (McDermott et al., 2011; Vitiello, 2009). These findings suggest that certain content areas are more strongly related to particular domain-general skills than others. For example, Nayfeld et al. (2013) found that EF, another domain-general skill related to higher school readiness, predicted significantly greater gains in children's science knowledge across the Head Start preschool year when compared to gains in math, vocabulary, and listening comprehension. These findings indicated that domain-general skills like approaches to learning might have a stronger relationship to science than other content areas. However, empirical research must be conducted to test how approaches to learning may differentially relate to science, math, vocabulary, and listening comprehension, respectively.

### 1.3. Current study

Approaches to learning are a set of skills that have been shown to predict math and language outcomes, but this relationship has not been extended to science. Recent emphasis on the importance of incorporating more early childhood science in the classroom highlights the need to identify skills that can enhance children's science learning. This study was the first to examine the longitudinal relationship between approaches to learning and gains in four distinct school readiness outcomes (science, math, listening comprehension, and vocabulary) from fall to spring in a sample of preschool-aged children attending an urban Head Start program. We used a structural equation modeling (SEM) framework to examine the differential relationships between approaches to learning and science, math, vocabulary, and listening comprehension. First, it was hypothesized that approaches to learning would significantly predict gains in science. Second, based on prior research showing that EF predicts gains in science more than math, vocabulary, and listening comprehension (Nayfeld et al., 2013) and that approaches to learning predict mathematics ability more than vocabulary, and listening comprehension (McDermott et al., 2011; Vitiello, 2009), it was hypothesized that approaches to learning would predict greater gains in science than in math and greater gains in math than vocabulary and listening comprehension.

## 2. Methods

### 2.1. Participants

Participants were 397 randomly sampled children, across 37 classrooms, in Head Start centers in low-income neighborhoods in a large urban county in the Southeast United States. Participants were stratified by age and gender prior to sampling, with 8–10 children sampled per classroom, to allow for the control of classroom-level effects and ensure a representative sample across child characteristics. The sample was comprised of predominately African American (68.5%, $n = 272$) and Latino children (31.5%, $n = 125$). Children ranged from 3 to 5 years of age at the time of the first assessment (36 to 59 months; $M = 47.70$, $SD = 7.03$) and 49.6% were male ($n = 197$). All children met the federal income requirement for enrollment in Head Start, indicating a sample of children from low-income families.

### 2.2. Measures

#### 2.2.1. Math and language school readiness

*The Learning Express* is an academic direct assessment designed and validated specifically for low-income, at-risk preschool children (McDermott et al., 2009). Children are assessed individually by a trained assessor using a large flip-book of pages that depict letters, pictures, and/or numbers. The test has four subscales that are administered in the following order: Vocabulary (58 items), Mathematics (57 items), Listening Comprehension (37 items), and Alphabet Knowledge (52 items). Items from the three language subscales are either receptive or expressive, and assess competencies such as picture and letter naming, word reading, and comprehension of syntax. Math items are also presented in either receptive or expressive formats (some of which require the manipulation of objects), and assess basic math competencies including counting, cardinality, seriation, and addition/subtraction. The two available forms (A and B) are counterbalanced. Each form includes a set of items ordered by difficulty, and each item is scored as either correct or incorrect. Raw scores for each of the four subscales are converted to an interval-level score by the instrument authors using a two-parameter Item Response Theory (IRT) analysis. Reliability across subscales range from 0.93 to 0.98. External and predictive validity was established for all subscales (McDermott et al., 2009).

#### 2.2.2. Science school readiness

The Lens on Science assessment (*Lens;* Greenfield, 2015) is a computer-adaptive, IRT-based direct assessment of science. This assessment was specifically designed to detect growth in the Head Start population. Items cover science practice skills, cross-cutting concepts and science content from life science, earth and space sciences and physical and energy sciences as defined by the National Research Council's conceptual framework for science education (NRC, 2012). During the assessment, children are placed in front of a touch-screen tablet and given headphones to listen to prompts instructing them to respond. For example, one item displays a large picture of a sea turtle and the child is told "This is a turtle. Touch the part of the turtle that helps it swim." Boxes then appear around the head, arm, and shell of the turtle and the child must touch the box around the arm of the turtle to score correctly. Before beginning the assessment children first pass a readiness screening demonstrating their ability to follow instructions and respond to the three formats of presentations of items.

An IRT ability score is obtained in approximately 15 min with the administration of approximately 35–40 items. Lens currently contains an item bank of 499 items calibrated using the dichotomous Rasch model, scaled to have a mean item difficulty of zero and unit-logit metric. For a sample of 1753 students, the average standard error of the Rasch ability estimate was 0.31 (on the unit-logit metric), which corresponds to a reliability of 0.87 (Greenfield, 2015).

#### 2.2.3. Approaches to learning

The Learning-to-Learn Scale (LTLS) is a teacher-report measure of children's learning behaviors (McDermott et al., 2011). It is a 55-item rating scale on which the teacher indicates whether a given behavior "does not apply," "sometimes applies," or "consistently applies" to each child. A factor analysis of this measure revealed seven unique dimensions, which include strategic planning, effectiveness motivation, interpersonal responsiveness in learning, vocal engagement in learning, sustained focus in learning, acceptance of novelty and risk, and group learning, as well as a uni-dimensional factor of general learning behavior. The measure demonstrates external validity and concurrent validity when compared with the cognitive subscale scores of the Learning Express, other norm-referenced tests, and teachers' assessments of language and numeracy, in addition to high reliability ($\alpha = 0.97$) (McDermott et al., 2011).

### 2.3. Procedure

Consent was obtained from center directors, teachers, and parents. Children were assessed on science, math, and language outcomes in the fall and spring of the 2012–13 school year. Teachers were asked to complete the approaches to learning rating scale during the winter of the same school year. Direct assessments were conducted in a quiet location outside of the classroom on separate days, and lasted approximately 20 min each. Assessments were administered by graduate or undergraduate students, who were trained to be reliable. Demographic information was obtained from the centers at the beginning of the year.

### *2.4. Data analytic plan*

All analyses were conducted in a structural equation modeling (SEM) framework to allow for the construction of path models and Full Information Maximum Likelihood (FIML) estimation to account for missing data, and the nested nature of the data (Muthén & Muthén, 2012). Children were nested within classrooms, and thus, classrooms were entered into the model as a cluster variable. To determine model fit, the Bentler comparative fit index (CFI) was examined based on the criteria that values >0.95 were considered acceptable fit (Bentler, 1990; Browne & Cudeck, 1992). The root mean square error of approximation (RMSEA) was also examined, with values below 0.06 considered adequate model fit (Browne & Cudeck, 1992). In addition, the standardized root mean square residual (SRMR) was examined, with values below 0.08 considered acceptable model fit (Hu & Bentler, 1999). The chi-square test of model fit was significant [$\chi^2(12) = 56.45$, $p < 0.001$], however, it was not utilized in this analysis as an indicator of fit because of the large sample size. The chi-square fit index is overly sensitive to sample size, and when samples are large, it is often significant even if the model fits the data (Kline, 2011). Missing data (9.01% of all data points) were accounted for with FIML, using available data to estimate the missing parameters (McCartney, Burchinal, & Bub, 2006). Additionally, Littles Missing Completely at Random (MCAR) analyses were conducted and data were indeed MCAR [$\chi^2(77) = 93.29$, $p = 0.10$].

To determine the relationship between approaches to learning and spring school readiness outcomes, each individual school readiness outcome (science, math, listening comprehension, and vocabulary) was regressed on the general score of approaches to learning. For each outcome, the respective fall score was entered into the model to control for baseline ability level. Additionally, ethnicity, age, and gender were entered as covariates for all analyses. The alphabet knowledge subscale of the Learning Express was omitted from the current analyses for theoretical and empirical reasons. Given the rote nature in which a child learns the letters of the alphabet (Windfuhr & Snowling, 2001), we hypothesized that alphabet knowledge would be less related to approaches to learning than science, math, or language which often require the use of higher-order thinking skills and are learned through interactions and hands on experiences (Nayfeld et al., 2013). Our initial data analyses supported this hypothesis, as model fit improved with the removal of the alphabet knowledge subscale. Given that children were nested within classrooms, intra-class correlations (ICC's) were calculated to determine the amount of variability in the outcomes at the classroom level. For the Learning Express (math and language), 4.70% of the variability in child's scores was at the classroom level and 0.10% of the variability in the Lens on Science assessment was at the classroom level. Standardized beta coefficients for each outcome were analyzed to determine the significance of the relationships.

## 3. Results

Descriptive statistics for all variables are presented in Table 1. All variables were assessed for skewness and kurtosis and found to be normally distributed. Correlations between all baseline scores and outcomes are presented in Table 2. The Learning Express was missing 2% of the data in the fall and 13% in the spring; the Lens on Science was missing 11% of the data in the fall and 16% in the spring; and the Learning-to-Learn Scale was missing 15% of the data in the winter.

The general score of approaches to learning was used to predict spring school readiness outcomes controlling for fall scores, ethnicity, age, and gender. In the initial model, spring vocabulary scores were highly correlated with the other spring outcomes (see Table 2), thus spring vocabulary was entered as a covariate, which significantly improved model fit. This model was retained and adequately fit the data, according to CFI and SRMR values (see Fig. 1). The RMSEA was higher than the currently accepted standard of 0.06. However, the RMSEA can also be overly sensitive to sample size and should be interpreted with caution (Browne, MacCallum, Kim, Andersen, & Glaser, 2002; Hu & Bentler, 1998).

**Table 1**
Descriptive analyses for all study variables.

| | N | Mean | Standard deviation (range) |
|---|---|---|---|
| Approaches to learning | 339 | 53.25 | 7.92 (34.4–75.1) |
| Fall science | 352 | 201.63 | 45.67 (71.5–320) |
| Spring science | 333 | 214.83 | 45.80 (81.5–332) |
| Fall math | 391 | 175.52 | 48.46 (72.6–308.1) |
| Spring math | 346 | 214.37 | 42.77 (72.6–311.2) |
| Fall listening comp. | 391 | 181.22 | 51.11 (75.6–266.9) |
| Spring listening comp. | 346 | 208.32 | 39.29 (75.6–273.4) |
| Fall vocabulary | 391 | 176.77 | 55.86 (62.4–310.6) |
| Spring vocabulary | 346 | 208.92 | 47.51 (62.4–311.1) |

*Note.* School readiness scores are standardized on the same metric ($M = 200$, $SD = 50$).

Approaches to learning significantly predicted gains in science readiness across the school year, supporting the first hypothesis. Additionally, approaches to learning trended towards, but did not reach significance in predicting gains in math, nor did it significantly predict gains in vocabulary or listening comprehension, offering marginal support for the second hypothesis. For standardized and unstandardized path coefficients, see Table 3. For the full model, see Fig. 1.

## 4. Discussion

The purpose of this study was to examine approaches to learning within a SEM framework to test its ability to predict school readiness outcomes (i.e. science, math, vocabulary and listening comprehension). This study is the first to extend the relationship between approaches to learning and academic outcomes to the preschool science domain. Findings supported recent research that shows domain-general skills (e.g. EF) are better predictors of gains in early science than gains in other school readiness domains (Nayfeld et al., 2013). This study extended these findings to another important set of domain-general skills, approaches to learning.

The first hypothesis was supported. Approaches to learning was a significantly better predictor of gains in science knowledge than math, vocabulary, and listening comprehension. This finding is consistent with previous research showing that approaches to learning in preschool is important for later science achievement in elementary school (McDermott et al., 2014), and extends this work to demonstrate a predictive relationship between preschool children's approaches to learning and their science achievement across the school year. This result is consistent with the theory that approaches to learning facilitates science exploration, given the competencies needed to effectively engage in and learn science content (Greenfield et al., 2009). Science is an iterative process that engages children in trial and error, experimentation, and group learning, which all require persistence, motivation, engagement with others, and attention. In other words, positive approaches to learning skills help children directly engage in science content and learning.

Findings were less conclusive for math, vocabulary, and listening comprehension. The second hypothesis that approaches to learning would predict greater gains in math than vocabulary and listening comprehension, was marginally supported; math gains trended towards significance, while vocabulary and listening comprehension gains did not. This pattern of findings is somewhat consistent with previous studies. Some research has demonstrated a lack of significant findings between approaches to learning and vocabulary, specifically (Fantuzzo

**Table 2**
Correlations between school readiness outcomes, approaches to learning (ATL), and baseline school readiness.

| | ATL | Fall sci. | Fall math | Fall list comp. | Fall vocab. | Spring sci. | Spring math | Spring list comp. | Spring vocab. |
|---|---|---|---|---|---|---|---|---|---|
| ATL | 1.00 | 0.39** | 0.40** | 0.32** | 0.30** | 0.36** | 0.39** | 0.28** | 0.24** |
| Fall sci. | 0.39** | 1.00 | 0.62** | 0.52** | 0.63** | 0.63** | 0.54** | 0.52** | 0.57** |
| Fall math | 0.40** | 0.62** | 1.00 | 0.57** | 0.64** | 0.53** | 0.75** | 0.43** | 0.57** |
| Fall list comp. | 0.32** | 0.52** | 0.57** | 1.00 | 0.61** | 0.51** | 0.49** | 0.43** | 0.53** |
| Fall vocab. | 0.30** | 0.63** | 0.64** | 0.61** | 1.00 | 0.54** | 0.56** | 0.51** | 0.68** |
| Spring sci. | 0.36** | 0.63** | 0.53** | 0.51** | 0.54** | 1.00 | 0.51** | 0.48** | 0.54** |
| Spring math | 0.39** | 0.54** | 0.75** | 0.49** | 0.56** | 0.51** | 1.00 | 0.43** | 0.63** |
| Spring list comp. | 0.28** | 0.52** | 0.43** | 0.43** | 0.51** | 0.48** | 0.43** | 1.00 | 0.53** |
| Spring vocab. | 0.24** | 0.57** | 0.57** | 0.53** | 0.68** | 0.54** | 0.63** | 0.53** | 1.00 |

** $p < 0.01$.

et al., 2011; Vitiello, 2009), while other studies have shown links between approaches to learning and achievement in math, vocabulary, and listening comprehension (Fantuzzo et al., 2004; McDermott et al., 2014).

Some studies seem to point to a domain-specific effect of approaches to learning, such that they may be more influential for math learning compared to language learning (McDermott et al., 2011; Ponitz et al., 2009; Vitiello, 2009). Researchers have posited that this may be the case because children are exposed to more literacy and language instruction compared to math and science, which makes the cognitive processes involved in learning the material more automatic and less dependent upon the activation of domain-general learning skills (Connor et al., 2006; Miller et al., 2005; Ponitz et al., 2009). When presented with novel material, approaches to learning (e.g. persistence, motivation, acceptance of novelty and risk), may be particularly important for engaging in and retaining this information. Findings from our study marginally support this idea given that approaches to learning trended towards predicting gains in math, but not vocabulary or listening comprehension.

Another potential reason for the lack of findings with math, vocabulary, and listening comprehension could be due to measurement. The Learning Express (used to measure these three outcomes) was developed with a smaller and culturally distinct Latino sample, consisting of approximately 17% Latino children from the Northeast United States. The current sample has nearly twice the percentage of Latino children (32%) from Miami-Dade County, which represents a unique region where Spanish predominates over English in many neighborhoods and schools (U.S. Census Bureau, 2010). These linguistic and cultural

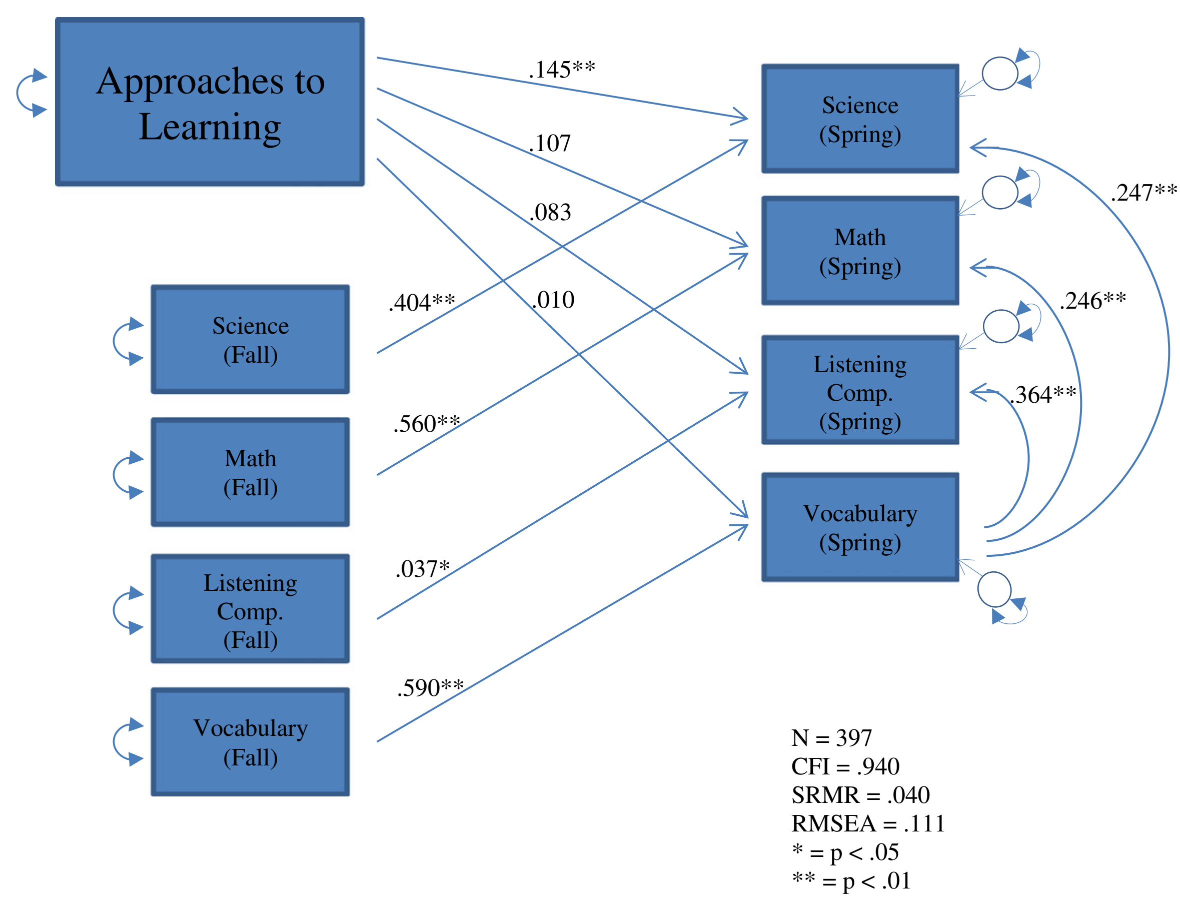


**Fig. 1.** Structural equation model of approaches to learning predicting spring outcomes, controlling for fall scores, child age, gender, ethnicity and spring vocabulary. All reported path coefficients are standardized for unstandardized coefficients see Table 3.

**Table 3**
Approaches to learning predicting spring school readiness outcomes: unstandardized and standardized coefficients.

| | Unstandardized | Standard error | Standardized | p-Value |
|---|---|---|---|---|
| Science | 0.804 | 0.250 | 0.145 | 0.001 |
| Math | 0.535 | 0.282 | 0.107 | 0.062 |
| Vocabulary | 0.055 | 0.310 | 0.010 | 0.859 |
| Listening comp. | 0.399 | 0.302 | 0.083 | 0.176 |

differences may indicate that the Learning Express functions differently in this population, potentially explaining the divergent results between previous research and our own.

### *4.1. Implications, limitations, and future directions*

Math and language are foundational school readiness domains; however, findings from our study suggest that science is also an important domain to measure as it relates differentially to important domain-general school readiness predictors and may offer valuable and unique information, beyond what assessments of math and language typically provide. By nature, science learning requires not just content knowledge, but also broader cognitive skills, such as higher-order thinking, comparison, reasoning, and reflection (Nayfeld et al., 2013). Given that science was the only content domain that was significantly predicted by these learning behaviors, these results provide support for future research focused on approaches to learning as a mechanism for facilitating science education. This is an important line of research, as both research and policy suggest that science is an ideal learning domain for young children and needs to be a greater focus of early childhood education (Brenneman, 2011).

If the development of domain-general skills like approaches to learning will facilitate young children's engagement in science learning, these skills should be the focus of further research and intervention work. Similarly, in considering the great utility of approaches to learning during early childhood science experiences, it seems logical that children would be provided many opportunities to practice their approaches to learning skills during science activities. Thus, it may be the case that not only do approaches to learning help children learn science, but science could serve as a context for the practice and improvement of approaches to learning. It is challenging to teach approaches to learning in isolation; thus, embedding these skills in scientific academic content may help teachers advance the development of approaches to learning within a broader framework.

It is beyond the scope of this study to determine the bi-directionality of the relationship between approaches to learning and science. Our data speak only to the role of approaches to learning in predicting children's science achievement. However, there could be a bidirectional relationship, such that science knowledge and learning also improves approaches to learning over time. Such an approach is supported by a recent conceptual model proposed by Snow (2007), which describes an integrative view of children's school readiness. Snow's theoretical model asserts that while children's capacities across domains are unique, they dynamically influence each other over time, encouraging researchers and practitioners to examine the interrelations among key components of school readiness, particularly in diverse populations of children (Snow, 2007). Given the national focus on the improvement of science education (Morgan et al., 2016), further research is warranted to explore the dynamic relationship between these two pivotal school readiness domains.

Future research should also examine the relationship between science and increases in approaches to learning in the context of an evidence-based science intervention. Specifically, studies should evaluate whether interventions focused on approaches to learning increase science readiness, and whether early science interventions improve children's approaches to learning. Given the scarcity of science pedagogy in Head Start classrooms, it is possible that the magnitude of the relationship between science and approaches to learning may be even greater if science were a more prominent component of the curriculum.

## 5. Conclusion

This study was the first to demonstrate that approaches to learning, a set of domain-general skills, predict spring science competence, controlling for fall science competence in ethnically diverse preschoolers from low-income families. Adaptive approaches to learning (i.e. strategic planning, effectiveness motivation, interpersonal responsiveness in learning, vocal engagement, sustained focus, acceptance of novelty and risk, and group learning) are highly useful as children engage in science experiences and investigate science concepts such as cause and effect and force and motion, in everyday learning. These findings are the first to empirically demonstrate a unique relationship between approaches to learning and science, making an important contribution to the literature examining approaches to learning and academic achievement in preschool populations from low-income backgrounds.

This is a critical finding given the national achievement gap that exists in the United States, in preschool and beyond, and the need for improving science education in the United States, starting in early childhood (Greenfield et al., 2009; Morgan et al., 2016). Children attending Head Start who have greater approaches to learning seem to learn more science across the year, which may suggest that intentionally fostering their approaches to learning in preschool could boost their science learning and potentially help narrow the school readiness and science achievement gaps. These results provide justification for future research that explores whether improving children's approaches to learning facilitates their science learning and that examines best teaching practices that could help children simultaneously develop both of these critical skills.

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