DEANS FOR IMPACT

THE SCIENCE
OF EARLY LEARNING

HOW YOUNG CHILDREN
DEVELOP AGENCY, NUMERACY, AND LITERACY

Table of Contents

DEANS FOR IMPACT

About The Science of Early Learning

The purpose of *The Science of Early Learning* is to summarize existing research related to how young children (from birth to age eight) develop skills across three domains: agency, literacy, and numeracy. This document is intended to serve as a resource to anyone who is interested in our best scientific understanding of how young children develop control of their own behavior and intentions, how they learn to read and write proficiently, and how they develop the ability to think mathematically.

For each domain, we have identified several key questions about learning and provided a short list of principles of learning science that inform the answers to each question. Further, we have connected these principles to a set of practical implications for specific teaching strategies. And throughout this document, we generally refer to "educators" as teachers, parents, caregivers, and anyone else involved in fostering the early learning of young children.

These questions are not meant to encompass everything that is important to know within each domain, nor do we believe that agency, literacy, and numeracy represent all that young children should learn. Further, many young children – including those with special-learning needs and dual-language learners – will need additional supports beyond what is discussed here. This report should be considered a starting point, not an end point, for exploring the science of early learning. But Deans for Impact believes that everyone involved in educating young children should be familiar with the questions included here and our best scientific understanding of the answers to them.

We see the domains of agency, literacy, and numeracy as interdependent. As children develop a sense of self and the ability to self-regulate, they are better able to persist in literacy and math activities. Likewise, as children develop their literacy and numeracy skills, they will grow in confidence and independence, strengthening their sense of agency. Thus, while we have listed the scientific principles included in each domain in roughly sequential order — with new skills building on previous ones — we recognize there will be variations in the development of every child and have deliberately refrained from putting age-specific guidance in this report.

This document may be cited as:
Deans for Impact (2019). *The Science of Early Learning.* Austin, TX: Deans for Impact.

How do young children develop a sense of self?

Principles from Learning Science

▶ "Sense of self" refers to someone's perceptions, attitudes, and beliefs about themselves. Young children gradually develop a sense of self over time – it is not yet stable during early childhood.[1]

▶ Secure attachments, which require sensitive and emotionally-responsive care, are the primary component of developing a positive sense of self. Conversely, inconsistent or stressful relationships leave children vulnerable and negatively influence the development of a child's sense of self.[2]

▶ Around the age of two, young children begin to understand the concept of "me" and start to feel self-conscious emotions such as shame or pride.[3] They begin to associate concrete characteristics with themselves such as hair color, height, preferences, and perceptions of skills.[4]

▶ If a young child develops a secure sense of self, this leads to increased confidence in their current and future abilities, including cognitive, academic, social, and physical abilities.[5]

Practical Implications

▶ Educators should provide emotionally-responsive and sensitive care, ensuring warm, stable, and reliable environments and relationships. This should be done through consistently responding to cues and verbalizations, implementing routines like a morning message, and following predictable schedules.

▶ Educators can provide young children with opportunities to learn about themselves through mirrors, photos, and classroom activities, including games like "Head, Shoulders, Knees and Toes." Asking children open-ended questions about themselves, their preferences, and opinions helps them reflect on and understand themselves.

▶ Environments and interactions should reflect the cultures and diversity of families in the classroom and the wider community.

[1] Harter, 2015
[2] Shirvanian & Michael, 2017
[3] Lewis, 2011
[4] Harter, 2015
[5] Orth, Robins, & Widaman, 2012

DEANS FOR IMPACT

How do young children begin to respect others?

Principles from Learning Science

▶ The ability to recognize emotions is a precursor to emotional regulation and perspective taking. It is essential for young children to develop the ability to attribute intentions, knowledge, perspectives, and emotions to others – and to understand that these mental states may be different than their own.[6]

▶ Empathy, the ability to imagine another's emotional experience, develops over time. Young children often look at how others react to a situation and then react similarly.[7]

▶ Understanding that other people may think differently, and having empathy for others, are precursors for positive social behaviors such as sharing, cooperating, and contributing.[8]

Practical Implications

▶ Educators can nurture emotional recognition by talking about early feelings frequently, both by talking about their own and helping children label theirs. "It looks like you are frustrated." "That smile tells me you're happy."

▶ Children naturally practice taking another's perspective through sustained imaginary play. Educators can further this development by using story time as an opportunity to consider characters' perspectives or using social stories to discuss common social dilemmas and involve children in solving them.

▶ Educators can develop empathy and respect for others by building a sense of community in the classroom, defining shared expectations, and fostering shared responsibility for materials, the space, and each other. Children benefit from opportunities to care for living things, such as tending to plants, creating get-well cards for a sick classmate, and having a class pet.

▶ Educators should reflect the diversity of children and their families in classroom materials, books, and activities (including holidays), and strive to eliminate stereotypical representations.

▶ Educators should avoid imposing inappropriate expectations on young children, such as asking, "How would it make you feel?" in response to a conflict. This can cause feelings of shame in young children who do not have well-developed perspective-taking abilities. Avoid using phrases such as "use your words" without previously and intentionally teaching children how to express emotions.

---

[6] Carlson, Koening, & Harms, 2013

[7] Walden & Ogan, 1988

[8] Brownwell, 2013; Eggum, et al., 2011; Walden & Ogan, 1988; White & Carlson, 2015

3 | How do young children learn to self-regulate their behavior?

Principles from Learning Science

▶ To self-regulate their behavior, children need to:
(1) remember their goals;
(2) suppress impulses and not respond to distractions; and
(3) be able to change how they think and react to things.
Together, these skills are called executive function and they show the most rapid development in early childhood (but continue to mature into young adulthood).[9]

▶ When faced with a challenge, children can build their capacity to self-regulate by imagining what someone more skilled at emotional and behavioral regulation would do in their situation.[10]

▶ Establishing routines helps young children learn to self-regulate their own behavior, but it is important to continue to provide new opportunities and challenges to exercise self-regulation skills and to nurture their growth.[11]

Practical Implications

▶ Educators can scaffold the ability of young children to self-regulate behavior by striving for consistency and predictability. Use consistent schedules and involve children in plans for the day.

▶ To improve self-regulation, educators can help children think through scenarios before they occur (e.g., students wanting to be in the front of the line to go outside), and use cues and subtle reminders to help children recall agreed - upon behavior expectations. Educators should remind children of their options for managing their emotions and controlling their impulses (e.g., by placing a hand on a shoulder, or referring to a poster of classroom community expectations).

▶ Executive function skills benefit from intentional instruction integrated into playful experiences. This includes games that require impulse control such as Simon Says or freeze dance, using role-play to practice handling a difficult situation, such as waiting for a turn or persevering through a difficult activity.

▶ Avoid long wait times between classroom activities. This can burden a child's ability to self-regulate behavior. If a long wait time is unavoidable, strive to have alternative activities available, such educational songs or games, for children to participate in.

---

[9] Zelazo, Blair, & Willoughby, 2016; Carlson, Zelazo, & Faja, 2013
[10] White & Carlson, 2015
[11] Diamond & Lee, 2011

DEANS FOR IMPACT

Principles from Learning Science

▶ The need for independence is essential to human growth and learning. A sense of independence (or autonomy) is critical for young children to be motivated to accomplish their goals.[12]

▶ To develop independence, young children must be provided with choices, given the opportunity to pursue their own initiatives, and supported just enough without adults taking control and doing something for them that they can do themselves.[13]

▶ Providing young children with experiences that require effort – but are achievable – will help them to develop their independence. These experiences can include support from adults until they are ready to do them independently.[14]

▶ The beliefs young children hold about their own intelligence – and whether it is fixed or can grow over time – impacts their self-concept and approaches to learning. If they believe their intelligence can grow, young children will be more likely to enjoy learning, question and propose ideas, try new things, and overcome challenges.[15]

Practical Implications

▶ Educators can help young children develop their independence by providing opportunities to make choices and decisions (within limits), and allowing them to experience the consequences of their choices. This can be achieved by helping children develop and follow simple plans, such as thinking through the steps to build a block city.

▶ The method of instruction is as important as the instruction. Educators should balance brief, intentional instruction on new concepts with opportunities for choice and playful practice.

▶ When providing instruction, start by giving two- or three-step instructions and demonstrations to align with young children's capabilities for recall and attention, and add additional detail as children's retention matures. It is equally important to allow children to correct their own mistakes.

▶ Educators should avoid doing things that may inhibit young children from developing independence – such as offering incentives like sticker charts or rewards for good behavior – because the prize becomes the goal more than learning.

▶ Avoid use of generic exclamations of praise such as "good job" or using phrases such as "You're a big boy now" that assign an expectation to gender, age, race, or culture.

[12] Deci & Ryan, 2000

[13] Distefano et al., 2018

[14] Bernier, Carlson, Deschênes, & Matte-Gagné, 2012; Distefano et al., 2018

[15] Dweck, Walton, & Cohen, 2014

5 How do young children learn the meaning of the alphabet?

Principles from Learning Science

▸ All writing systems employ a visual code for representing spoken language. Learning to read and write requires children to crack the code for their language.[16]

▸ The writing system for English is alphabetic, which means each letter in the alphabet is a symbol for a spoken sound called a **phoneme**. Any letter or group of letters that represent a single phoneme is called a **grapheme**.[17]

▸ Most children will not "naturally" learn that the letters in the English alphabet represent specific sounds. Instead, these letter-sound relationships must be explicitly taught.[18]

▸ Systematic phonics instruction is the most effective, evidence-based way to ensure that young children learn letter-sound relationships.[19]

▸ Children need to develop **phonemic awareness** along with understanding of how spoken sounds link to letters. Phonemic awareness includes the ability to hear and recognize individual sounds in words; to segment, or break apart, the sounds in words; and to blend, or connect and combine, the sounds to write or read words.[20]

▸ Some words in English follow complex spelling patterns, and the most common of these words should be taught explicitly.[21]

Practical Implications

▸ Educators should provide young children with experiences to learn letters. Providing children opportunities to write their own names is particularly powerful because children will have intrinsic motivation to learn their names. Labeling their work is another example.

▸ Educators should teach both letters and sounds explicitly and systematically, beginning with simple single-letter graphemes (e.g., D, A, T) and moving to more complex ones (e.g. EE, TH). Children may find learning easier when the letter name contains its sound (such as O and F).[22]

▸ Asking students to recite the letters in the alphabet is not enough to teach them how the alphabet works. They should receive explicit instruction that teaches the sounds that letters and combinations of letters represent; the relationships of spelling patterns and pronunciations; and how to "decode" printed words to oral ones. Instruction should also include retrieval practice, in which students are asked to say the sound that various letters and combination of letters represent within the set they are working on and have already mastered, gradually expanding to add new graphemes.

▸ During phonics instruction, teachers should have students both read and write graphemes and words using those graphemes. For example, a teacher might introduce the vowel graphemes "ai" and "oi", giving students opportunities to read the sounds alone by first flashing them on cards, then embedding them in simple words such as "rain" or "coin", then in more complex words (including only graphemes they have already learned, e.g. "rained", "explained"), and finally in sentences such as, "The train stopped in the city."

▸ Teachers should introduce high-frequency "sight words" with complex spelling patterns. Children should not be encouraged to guess these words, but rather to focus on the letters and their sequence, including any unusual parts of their spelling.

[16] Castles, Rastle, & Nation, 2018
[17] Castles, Rastle, & Nation, 2018
[18] Foulin, 2005; Castles, Rastle, & Nation, 2018
[19] Castles, Rastle, & Nation, 2018
[20] Ball & Blachman, 1991
[21] Castles, Rastle, & Nation, 2018
[22] Phillips, Piasta, Anthony, Lonigan, & Francis, 2012

DEANS FOR IMPACT

Principles from Learning Science

▸ In order to read, children must develop concepts of print, such as the idea of reading text from left to right, or matching spoken words to written words. Adults support this development by calling explicit attention to the printed text while reading to and with their child.[23]

▸ As children become more skilled at reading, they rely less on decoding words and begin to recognize words automatically and easily – that is, they become **fluent** at word recognition.

▸ Fluent reading supports comprehension by allowing children to focus on thinking about meaning instead of sounds, and by allowing children to remember the gist of a text, rather than a series of individual words.

▸ The key factor supporting young children in transitioning from beginner, effortful decoders to fluent readers is lots of reading practice with varied texts.[24]

▸ Over time, children can begin to understand that parts of words are associated with particular meanings – for example, that "helpful" has two parts (help/ful). This ability is called **morphological awareness**.

▸ Developing and sustaining a child's intrinsic motivation to read – rather than using extrinsic rewards or other incentives – is more likely to result in long-term reading habits.[25]

Practical Implications

▸ While reading aloud, teachers and caregivers should point to text, word by word; show the connections between text and images; and guide children to participate in reading some words, such as those that repeat throughout the text.

▸ To develop a young students' speed and accuracy when reading, teachers can read aloud a brief passage of text to call attention to important elements in the passage, such as key words and punctuation. The student should practice reading the passage several times aloud for fluency with guidance and feedback on each read.

▸ Teachers can provide explicit instruction on morphology, or the recognition of word parts, to support students' transition toward more automatic, fluent word reading. Morphology instruction should include analysis of word families, including both the base parts of words (such as "jump" in "jumping" and "jumpy") and the add-on parts (such as "ing" and "y").[26]

▸ To make reading opportunities salient, books and other texts should be made readily available in as many contexts of a child's life as possible – around the house, in different parts of the classroom, in the car, and so on. But "independent reading" should not supplant other reading instruction: School time should be used for explicit instruction or guided practice when possible.[27]

[23] Piasta, Justice, Justice, McGinty, & Kaderavek, 2012; National Center for Family Literacy, 2009

[24] Stanovich & West, 1989

[25] Willingham, 2017

[26] Bowers, Kirby, & Deacon, 2010

[27] National Institute of Child Health and Human Development (NICHD), 2000

Principles from Learning Science

▸ Reading aloud to young children is most effective at developing vocabulary and conceptual understanding of story and text structures when it is interactive, including opportunities to ask questions, make predictions, or analyze the text.[28]

▸ Children must know not only the vocabulary but also understand the concepts, background information, and rich content knowledge related to the material they are reading. This helps them to make inferences while reading.[29]

▸ Children with richer, better-developed vocabularies who can read the words are able to comprehend a wider, more complex range of texts.[30]

▸ Reading a range of material on the same topic helps young children to develop content knowledge by creating a well-connected web of facts, ideas, and vocabulary words.[31]

▸ Explicit instruction in comprehension strategies can support young children in engaging with and understanding text. But reading comprehension strategies alone cannot compensate for lack of vocabulary or content knowledge.[32]

Practical Implications

▸ When reading to children, teachers should reflect on the topic or story and ask questions, prompting thought and comprehension. Children can extend the story into other areas of play, helping them explore the ideas within the text.[33]

▸ Children should read texts that are rich in content, not just about familiar, daily life contexts. Even young children benefit from learning about science, history, geography, and other cultures, and from reading classic stories that may be referenced in other works.

▸ Wide reading aloud of different books supports children in acquiring new vocabulary words from a text. If a child asks you to read that same story for the third time, go ahead!

▸ Educators can provide lessons modeling and guiding practice with comprehension strategies (e.g., making predictions or using context clues to determine the meaning of unknown words), but should not overdo it. There is minimal evidence that repeated, ongoing instruction in these strategies improve students' abilities to apply them.

[28] Dickinson, 2001; Wasik & Bond, 2001

[29] Willingham, 2006a

[30] Castles, Rastle, & Nation, 2018

[31] Wright & Cervetti, 2017; Cervetti, Wright, & Hwang, 2016; Neuman, Kaefer, & Pinkham, 2016

[32] Castles, Rastle, & Nation, 2018; Willingham, 2006b; Willingham, 2006a

[33] Rowe, 1998

Principles from Learning Science

▶ Fine motor control and drawing are young children's first steps toward writing. They will then progress to scribbles meant to mimic writing before reaching conventional writing and spelling.[34]

▶ Handwriting or transcription fluency has long-term impacts on students' writing ability. Systematic instruction in letter formation can support students in developing efficient, clear handwriting.[35]

▶ To write stories, young children must learn not only to handle a pencil or other writing device but also to generate ideas, elaborate upon them, and sequence and connect them coherently. Children develop these skills through scaffolded play, storytelling, writing practice, and in conversations – particularly with adults and older children.[36]

▶ Retelling stories that were read aloud helps young children understand narrative or story structure, which they can then apply to their own writing of stories.[37]

Practical Implications

▶ Educators can use models that show the number and the direction of strokes for each letter to help children produce the letter accurately and efficiently. Early childhood teachers in particular should monitor the production of the letters, as bad habits can be difficult to unlearn.

▶ Extended, repeated practice of the same letter should be avoided. Educators should emphasize frequent, small doses of practice rather than long, repetitive sessions.

▶ Early childhood classrooms should provide frequent opportunities for writing practice throughout the day, such as planning for play centers (e.g., "Draw and write what you are going to do in your play center"); reflecting after learning activities (e.g., "Draw and write what you learned about"); making writing materials accessible in all learning areas; and dedicating writing time.

▶ After reading a book, ask children to retell the entire story in detail. Use prompts and questions to encourage them to describe the action with specificity ("so what happened next?").

▶ During playtime, educators should participate in the action to support and model the development of more complex stories. For example, if a child is building a house with blocks, ask, "Oh no! A hurricane is approaching! Where should we go?". Educators should also ask questions that support the child in deepening their play scenario (e.g. "What are you going to do after constructing that castle?"). And after play, invite children to retell or explain their play scenario in depth.

---

[34] Cabell, Tortorelli, & Gerde, 2013

[35] Berninger, et al., 1997; Berninger, 1999; Graham, 1999

[36] Leong & Bodrova, 2012; Dunst, Simkus, & Hamby, 2012; Stadler & Ward, 2005

[37] Dunst, Simkus, & Hamby, 2012

Principles from Learning Science

▶ Young children often first learn to count procedurally, in which they can recite the count sequence – saying, "one, two, three, four," and so on.[38]

▶ To understand the purpose of counting, children need to understand one-to-one correspondence – that is, they must match what they count to actual objects. Young children then learn that the number of items they have counted is equal to the last number that was said – this is the **cardinality principle**. By learning this principle, children learn that counting determines the number of items in a set.[39]

▶ Understanding quantity involves many ideas beyond counting.[40] Numerical symbols play an especially important role in understanding quantity.[41]

▶ Games that involve moving pieces on linear boards and counting can play an important role in developing early understanding of quantity.[42]

Practical Implications

▶ Children naturally include counting in their play. Educators should also include counting in daily experiences.

▶ After learning the count sequence, young children must connect number words to collections of objects. Educators can teach counting by asking children to count out a certain number of objects, beginning with smaller numbers before progressing to larger ones. Eventually children should practice skip counting (such as counting in multiples of 2s or 10s).

▶ Educators should explicitly show students different representations of the same number: for instance, the Arabic numeral 3; the word "three"; a set of three identical objects; and a set of three different but related objects, such as three different pieces of fruit. Linking these representations helps children to apply them in new contexts in the future.

▶ To grasp quantity, educators must help students understand the following:
  ▪ If students have a set of, for example, 11 objects and they add one, there are now 12 objects, and they do not need to count all the objects again.
  ▪ Comparing the size of sets and ordering them by their size
  ▪ Quickly identifying the number of objects in a small set without counting (this is called "subitizing")
  ▪ Distinguishing numerical quantity, such as pieces of fruit in a bowl, and non-numerical quantity, such as water in a cup.

▶ Games such as Chutes and Ladders or other board games that involve counting help students to practice their counting and to connect representations of numbers in informal ways. Games can be especially helpful for children who have been unsuccessful learning numerical ideas in other settings.

---

[38] Sarnecka, Goldman, & Slusser, 2015
[39] Sarnecka, Goldman, & Slusser, 2015; Sarnecka & Gelman, 2011; Sarnecka & Wright, 2013
[40] Siegler & Braithwaite, 2017; Sarneka, Goldman, & Slusser, 2015
[41] Merkley & Ansari, 2016; Leibovich & Ansari, 2016
[42] Ramani & Siegler, 2008; Siegler & Ramani, 2009; Wilson et al., 2006; Kucian et al., 2011

DEANS FOR IMPACT

How do young children develop abstract knowledge of mathematical concepts?

Principles from Learning Science

▶ Young children begin to understand abstract mathematical concepts through concrete representations, and learn to apply what they know in new contexts by gradually transitioning from concrete to visual to abstract. **Manipulatives** – physical objects – can be useful tools for understanding mathematical problems when used in a structured, guided context.[43]

▶ Objects used as manipulatives for counting should progress from simple and uniform to complex and varied.[44]

▶ For a given concept, young children need to understand that symbols and abstract representations represent quantity, and these symbols should gradually replace manipulatives and concrete representations in how they think about quantity. This is called **concreteness fading**.[45]

Practical Implications

▶ Educators can support students in progressing from concrete to visual to abstract understandings by connecting representations. For example, while a kindergartener might solve 5 + 7 by counting out physical objects, the teacher might chart her strategy with visual representations (e.g. 5 circles and 7 circles), or an open number line showing that 5 + 5 = 10 (a "nice number"), and 10 + 2 =12, and representing the equation 5 + 7 = 12 on the chart.

▶ Over time, educators can guide students to progress from concrete modeling of physical objects to visual and abstract numerical ideas. This progression is particularly important in understanding place value.

▶ When learning to count, an effective manipulative might be a set of unifix cubes. As children learn, manipulatives should progress to more complex objects, (e.g., to chips of different colors and sizes, and then to different types of fruit, stones, shells, or blocks).

---

[43] Brown, McNeil, & Glenberg, 2009; Willingham, 2017; Ball, 1992
[44] Peterson & McNeil, 2013; Mix, 2008
[45] Brown, McNeil, & Glenberg, 2009

Principles from Learning Science

- Young children learn arithmetic by building on their prior knowledge. Addition builds on quantity, subtraction builds on addition, multiplication builds on addition and subtraction, and division further builds on these previous operations.[46]

- Young children will typically use a variety of basic strategies when first learning arithmetic, such as counting with their fingers. Over time, children should be able to solve basic arithmetic problems automatically from memory. Progress in using more efficient strategies is likely to be non-linear and gradual.[47]

- Children need to retrieve basic arithmetic facts fluently so that their working memory is freed up to solve more complex problems.[48]

- A child's ability to accurately compare the magnitude of numbers is related to their success in learning arithmetic. Young children use their understanding of magnitude to make sense of arithmetic problems and to check if their answers are correct.[49]

- Number lines play an important role in helping children to understand numerical magnitude, and continue to play a role with fractions and decimals in future years.[50]

Practical Implications

- Elementary teachers should develop arithmetic skills in young children by building on prior knowledge. For example, subtraction is the inverse operation of addition: if 9 + 3 = 12, then 12 - 3 = 9. Making these connections explicit for students helps them to flexibly apply arithmetic principles in the future.

- Fingers are a critical early representation of numbers and play an important role in supporting an early understanding of counting, addition, and subtraction. Educators should *not* discourage young children from using their fingers as they learn to add or subtract.[51]

- Educators should guide children to practice strategic thinking and accurate representation in counting based strategies. For instance, to find 3 + 5, they might first count up to 3, and then count 5 more. Educators can support children progressing towards more efficient strategies (e.g., counting on from 3, then beginning with the larger addend, 5), and in prompting children to model their solution accurately on paper in drawings and numbers.

- Teachers should ensure children practice basic number facts with the goal of reaching fluency, but also know that fluency takes time and develops gradually.

- Children can practice thinking about magnitude with number lines by accurately placing 15 on a scale of 1-100, or 200 on a scale of 1-1000. Estimation, beginning in preschool, and proportional models such as tape diagrams can help children to represent number relationships accurately.

[46] Siegler & Braithwaite, 2017; Lyons, Price, Vaessen, Blomert & Ansari, 2014; Deans for Impact, 2015
[47] Siegler & Braithwaite, 2017; Siegler, 2016
[48] Deans for Impact, 2015
[49] Lyons, Price, Vaessen, Blomert, & Ansari, 2014; Siegler, 2016
[50] Siegler & Braithwaite, 2017
[51] Berteletti & Booth, 2015

DEANS FOR IMPACT

12 | What should an effective math learning environment for young children include?

Principles from Learning Science

▶ Math anxiety can have profound negative impacts on learning. The structure of early math learning environments can greatly reduce the likelihood that young children will experience this anxiety.[52]

▶ There is no evidence that certain individuals are "math people" or that boys and girls learn math in substantively different ways.[53]

▶ Some children have persistent difficulties learning math. While varied teaching and targeted intervention can support their learning, researchers do not fully understand the causes of difficulty learning math or how to diagnose particular disabilities.[54]

Practical Implications

▶ Educators should take great care to avoid expressing negative feelings about math by saying things such as "I'm scared of math, just like you." Doing so will increase the likelihood of children experiencing math anxiety.

▶ A classroom rich in interesting math materials fosters enthusiasm for math. Appropriate materials include sorting and counting manipulatives, from unifix cubes to pinecones; scales, yardsticks, and rulers; and puzzles and patterned materials with obvious and less obvious shared characteristics.

▶ Educators must know that math anxiety is not necessarily correlated with skill. Children might experience math anxiety despite developing strong numerical skills, and they might struggle with concepts yet maintain a positive attitude toward math. Perceptions of poor performance can perpetuate math anxiety: A math program that moves too quickly and doesn't allow time to practice foundational skills is likely to perpetuate negative feelings toward math.

▶ Stereotypes about math ability and gender are unfounded. Individuals differ in their mathematical learning, but there is no convincing evidence we can identify which children are likely to be successful in math at a young age. Educators' expectations influence students' achievement, and they should hold all children to high expectations in math.

▶ Educators should avoid limiting opportunities for any children: Many children who struggle with math early on can return to a typical learning trajectory with varied teaching methods and targeted individual support.

[52] Maloney & Beilock, 2012
[53] Hutchinson, Lyons, & Ansari, 2019; Willingham, 2009
[54] Bugden & Ansari, 2014

Bernier, A., Carlson, S. M., Deschênes, M., & Matte-Gagné, C. (2012). Social factors in the development of early executive functioning: A closer look at the caregiving environment. *Developmental Science, 1*5(1), 12-24.

Brownell, C. A. (2013). Early development of prosocial behavior: Current perspectives. *Infancy, 18*(1), 1-9.

Carlson, S. M., Koenig, M. A., & Harms, M. B. (2013). Theory of mind. *WIREs Cognitive Science, 4*(4), 391-402.

Carlson, S. M., Zelazo, P. D., & Faja, S. (2013). Executive function. In P. D. Zelazo (Ed.), *Oxford library of psychology. The Oxford handbook of developmental psychology (Vol. 1): Body and mind* (pp. 706-743). New York, NY, US: Oxford University Press.

Deci, E. L. & Ryan, R. M. (2000). The" what" and" why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry, 11*(4), 227-268.

Diamond, A. & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science, 333*(6045), 959-64.

Distefano, R., Galinsky, E., McClelland, M. M., Zelazo, P. D. & Carlson, S. M. (2018). Autonomy-supportive parenting and associations with child and parent executive function. *Journal of Applied Developmental Psychology, 58*, 77-85.

Dweck, C. S., Walton, G. M., & Cohen, G. L. (2014). *Academic tenacity: Mindsets and skills that promote long-term learning.* Bill & Melinda Gates Foundation.

Eggum, N. D., Eisenberg, N., Kao, K., Spinrad, T. L., Bolnick, R., Hofer, C., Kupfer, A. S., & Fabricius, W. V. (2011). Emotion understanding, theory of mind, and prosocial orientation: Relations over time in early childhood. *The Journal of Positive Psychology, 6*(1), 4-16.

Harter, S. (2015). Self-development in childhood and adolescence. *International Encyclopedia of the Social and Behavioral Sciences*, 492-497.

Lewis, M. (2011). The self-conscious emotions. In R. E. Tremblay, M. Boivin, R. D. Peters (Eds.), M. Lewis (Topic ed.), *Encyclopedia on early childhood development.*

Orth, U., Robins, R. W., & Widaman, K. F. (2012). Life-span development of self-esteem and its effects on important life outcomes. *Journal of Personality and Social Psychology, 102*(6), 1271-1288.

Shirvanian, N. & Michael, T. (2017). Implementation of attachment theory into early childhood settings. *The International Education Journal: Comparative Perspectives, 16*(3), 97-115.

Walden, T. A. & Ogan, T. A. (1988). The development of social referencing. *Child Development, 59*(5), 1230-40.

White, R. E. & Carlson, S. M. (2015). What would Batman do? Self-distancing improves executive function in young children. *Developmental Science, 19*, 419-426.

Zelazo, P. D., Blair, C. B., & Willoughby, M. T. (2016). *Executive function: Implications for education* (NCER 2017-2000). Washington, DC: National Center for Education Research, Institute of Education Sciences, U.S. Department of Education.

DEANS FOR IMPACT

Ball, E. W. & Blachman, B. (1991). Does phoneme awareness training in kindergarten make a difference in early word recognition and developmental spelling? *Reading Research Quarterly, 26*, 49-66.

Berninger, V. W. (1999). Coordinating transcription and text generation in working memory during composing: automatic and constructive processes. *Learning Disability Quarterly, 22*(2), 99–112.

Berninger, V. W., Vaughan, K. B., Abbott, R. D., Abbott, S. P., Rogan, L. W., Brooks, A., Reed. E., & Graham, S. (1997). Treatment of handwriting problems in beginning writers: Transfer from handwriting to composition. *Journal of Educational Psychology, 89*(4), 652-666.

Bowers, P. N., Kirby, J. R., & Deacon, S. H. (2010). The effects of morphological instruction on literacy skills: A systematic review of the literature. *Review of Educational Research, 80*(2), 144-179.

Cabell, S. Q., Tortorelli, L. S., & Gerde, H. K. (2013). How do I write…? Scaffolding preschoolers' early writing skills. *The Reading Teacher, 66*(8), 650-659.

Castles, A., Rastle, K., & Nation, K. (2018). Ending the reading wars: Reading acquisition from novice to expert. *Psychological Science in the Public Interest, 19*, 5–51.

Cervetti, G. N., Wright, T. S., & Hwang, H. J. (2016). Conceptual coherence, comprehension, and vocabulary acquisition: A knowledge effect? *Reading and Writing, 29*, 761–779.

Dickinson, D. (2001). Book reading in preschool classrooms: Is recommended practice common? In D. K. Dickinson & P. O. Tabors (Eds.), *Building literacy with language: Young children learning at home and school* (pp. 175-203). Baltimore: Brookes.

Dunst, C. J., Simkus, A., & Hamby, D. W. (2012). Effects of reading to infants and toddlers on their early language development. *CELLreviews, 5*(4), 1-7.

Foulin, J. N. (2005). Why is letter-name knowledge such a good predictor of learning to read? *Reading and Writing, 18*, 129 - 155.

Graham, S. (1999). Handwriting and spelling instruction for students with learning disabilities: A review. *Learning Disability Quarterly, 22*(2), 78-98.

Leong, D. J. & Bodrova, E. (2012). Assessing and scaffolding make-believe play. *Young Children.* National Association for the Education of Young Children.

National Center for Family Literacy. (2009). *Developing early literacy: Report of the national early literacy panel.* Washington, DC: National Institute for Literacy.

National Institute of Child Health and Human Development (NICHD) (2000). Report of the National Reading Panel. *Teaching children to read: An evidence-based assessment of the scientific research literature on reading and its implications for reading instruction.* (NIH No. 00-4769) Washington, DC: U.S. Government Printing Office.

Neuman, S. B., Kaefer, T., & Pinkham, A. M. (2016). Improving low-income preschoolers' word and world knowledge: The effects of content-rich instruction. *Elementary School Journal, 116*, 652–674.

Phillips, B. M., Piasta, S. B., Anthony, J. L., Lonigan, C. J., & Francis, D. J. (2012). IRTs of the ABCs: children's letter name acquisition. *Journal of School Psychology, 50*(4), 461-481.

Piasta, S. B., Justice, S. B., Justice, L. M., McGinty, A. S., & Kaderavek, J. N. (2012). Increasing young children's contact with print during shared reading: Longitudinal effects on literacy achievement. *Child Development, 83*(3), 810-820.

Rowe, D. (1998). The literate potentials of book-related dramatic play. *Reading Research Quarterly, 33*, 10-35.

Stadler, M. & Ward, G. (2005). Supporting the narrative development of young children. *Early Childhood Education Journal, 33*, 73-80.

Stanovich, K. E. & West, R. F. (1989). Exposure to print and orthographic processing. *Reading Research Quarterly, 24*, 402–433.

Wasik, B. A. & Bond, M. A. (2001). Beyond the pages of a book: Interactive book reading and language development in preschool classrooms. *Journal of Educational Psychology, 93*(2), 243.

Willingham, D. T. (2017). *The reading mind: A cognitive approach to understanding how the mind reads.* John Wiley & Sons.

Willingham, D. T. (2006a). How knowledge helps: It speeds and strengthens reading comprehension, learning—and thinking. *American Educator, 30*(1), 30-37.

Willingham, D. T. (2006b). The usefulness of brief instruction in reading comprehension strategies. *American Educator, 30*(4), 39-50.

Wright, T. S. & Cervetti, G. N. (2017). Supporting vocabulary acquisition and comprehension with conceptually-coherent text sets. *24th Annual Meeting Society for the Scientific Study of Reading.* Halifax, NS.

Ball, D. L. (1992). Magical hopes: Manipulatives and the reform of math education. *American Educator, 16*(2), 14-18, 46-47.

Berteletti, I. & Booth, J. R. (2015). Perceiving fingers in single-digit arithmetic problems. *Frontiers in Psychology, 6*(226).

Bugden, S. & Ansari, D. (2014). When your brain cannot do 2 + 2: A case of developmental dyscalculia. *Frontiers for Young Minds, 2*(8).

Brown, M. C., McNeil, N. M., & Glenberg, A. M. (2009). Using concreteness in education: Real problems, potential solutions. *Child Development Perspectives, 3*(3), 160-164.

Deans for Impact (2015). *The Science of Learning.* Austin, TX: Deans for Impact.

Hutchinson, J. E., Lyons, I. M., & Ansari, D. (2019). More similar than different: Gender differences in children's basic numerical skills are the exception not the rule. *Child Development, 90*(1), 66-79.

Kucian, K., Grond, U., Rotzer, S., Henzi, B., Schönmann, C., Plangger, F., Gälli, M., Martin, E., & Von Aster, M. (2011). Mental number line training in children with developmental dyscalculia. *NeuroImage, 57*(3), 782-795.

Leibovich, T. & Ansari, D. (2016). The symbol-grounding problem in numerical cognition: A review of theory, evidence, and outstanding questions. *Canadian Journal of Experimental Psychology, 70*(1), 12-23.

Lyons, I. M., Price, G. R., Vaessen, A., Blomert, L., & Ansari, D. (2014). Numerical predictors of arithmetic success in grades 1-6. *Developmental Science, 17*(5), 714-726.

Maloney, E. A. & Beilock, S. L. (2012). Math anxiety: who has it, why it develops, and how to guard against it. *Trends in Cognitive Sciences, 16*(8), 404-406.

Merkley, R. & Ansari, D. (2016). Why numerical symbols count in the development of mathematical skills: Evidence from brain and behavior. *Current Opinion in Behavioral Sciences, 10*: 14-20.

Mix, K. S. (2008). Children's numerical equivalence judgments: Crossmapping effects. *Cognitive Development, 23*(1), 191-203.

Petersen, L. A. & McNeil, N. M. (2013). Effects of perceptually rich manipulatives on preschoolers' counting performance: Established knowledge counts. *Child Development, 84*(3), 1020-1033.

Ramani, G. B. & Siegler, R. S. (2008). Promoting broad and stable improvements in low-income children's numerical knowledge through playing number board games. *Child Development, 79*(2), 375-394.

Sarnecka, B. W. & Gelman, S. A. (2011). Six does not just mean a lot: preschoolers see number words as specific. *Cognition, 92*(3), 329-352.

Sarnecka, B. W., Goldman, M. C., & Slusser, E. B. (2015). How counting leads to children's first representations of exact, large numbers. In R. Cohen Kadosh & A. Dowker (Eds.), *Oxford handbook of numerical cognition* (pp. 291-309). NY: Oxford University Press.

Sarnecka, B. W. & Wright, C. E. (2013). The idea of an exact number: Children's understanding of cardinality and equinumerosity. *Cognitive Science: A Multidisciplinary Journal, 37*(8).

Siegler, R. (2016). Magnitude knowledge: the common core of numerical development. *Developmental Science, 19*(3), 341-361.

Siegler, R. S. & Braithwaite, D. W. (2017). Numerical development. *Annual Review of Psychology, 68*, 187-213.

Siegler, R. S. & Ramani, G. B. (2009). Playing linear number board games—but not circular ones—improves low-income preschoolers' numerical understanding. *Journal of Educational Psychology, 101*(3), 545-560.

Willingham, D. T. (2017). Do manipulatives help students learn? *American Educator, 41*(3), 25-30.

Willingham, D. T. (2009). Is it true that some people just can't do math? *American Educator, 33*(4), 14-19.

Wilson, A. J., Revkin, S. K., Cohen, D., Cohen, L., & Dehaene, S. (2006). An open trial assessment of "The Number Race," an adaptive computer game for remediation of dyscalculia. *Behavioral and Brain Functions, 2*(1), 1-16.