

What More Has Been Learned? The Science of Early Childhood Development 15 Years After *Neurons to Neighborhoods*

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ABSTRACT

The new Institute of Medicine/National Research Council report, *Transforming the Workforce for Children From Birth Through Age 8: A Unifying Foundation* (2015), begins with a summary of the science of early development and learning, with particular attention to discoveries during the past 15 years since the publication of *From Neurons to Neighborhoods* (National Research Council & Institute of Medicine, 2000). This article summarizes what has been learned during this period and its implications for practitioners who work with young children. New advances include better understanding of the scientific foundations for learning that develop during the first 3 years, the realization that early learning is more than just acquiring cognitive skills, knowledge of the influence of chronic stress and the significance of early relationships, and new understanding of the interaction of biology and environment in early learning.

In 2000, the National Research Council (NRC) and the Institute of Medicine (IOM) released the landmark report, *From Neurons to Neighborhoods: The Science of Early Childhood Development*. Commissioned because of Congressional and public interest in the implications of early brain research for understanding early childhood development, and with the realization that the social and economic circumstances of young children had changed in recent decades, the committee writing the report focused attention on several basic conclusions that have since become foundational to public awareness of the importance of the early years. These conclusions include:

- Human development is shaped by a dynamic and continuous interaction between biology and experience.
- The growth of self-regulation is a foundation of early childhood development that influences all domains of development.
- Nurturing human relationships are the “active ingredients” of healthy development.
- Early brain development is important, although the narrow focus on birth to 3 years old begins too late and ends too early.

- Children’s social competence and emotional well-being are as important to school readiness as are language and math skills.
- Social and economic disadvantage creates “striking disparities” in development that are apparent early and are predictive of later academic success.
- Early childhood programs are fragmented and require better coordination to address young children’s needs.
- There is an unacceptable gap between current knowledge of early childhood development and the implementation of that knowledge in programs and policies that support young children and their families.

Although most of the policy recommendations of the report have received little attention, *Neurons to Neighborhoods* contributed to a broader public awareness of the importance of early childhood development and articulated an agenda for further research that has been influential.

Early in 2015, the NRC and the IOM released a new report, *Transforming the Workforce for Children Birth Through Age 8: A*

Unifying Foundation. As with *Neurons to Neighborhoods*, the committee writing this report was charged to summarize the science of early development and learning and examine its implications for policy and practice. The focus, however, was on the professionals who provide care and education for children from birth to 8 years old. What are the implications of the science of early development for the preparation of a workforce to seamlessly support children’s development from birth through school entry? What do they need to know? How should they be trained and supported? What public policies would contribute to the development of an integrated system of services that best prepares young children for successful learning in the years that follow?

As a member of each committee, I was excited to see how much the science of early childhood development had advanced in the 15 years between the publication of each report. In this article, I highlight some of the significant advances in what researchers have learned, with particular focus on early childhood development. I also describe some of the implications of these discoveries for policy and practice.

Learning Begins Early, From Birth, and Is Rapid and Cumulative

From Neurons to Neighborhoods acquainted the public and policymakers with the importance of early childhood learning as a foundation for school readiness and later academic success. Summarizing what has been learned since then, the authors of *Transforming the Workforce* devoted considerable attention to the first 3 years, describing children’s thinking as “astonishingly competent, active, and insightful from a very early age” (IOM & NRC, 2015, p. 88).

To illustrate this, they summarized research showing that infants and toddlers create implicit theories that help them understand the actions of objects and the behavior of people, and these theories become progressively refined as young children learn more. Their early-emerging *theory of mind*, for example, helps 1-year-olds understand that people’s actions are goal-oriented, that others’ facial expressions reveal the emotions they are feeling, and that people are paying attention to what they are looking at and thus it is “on their minds” (Wellman, 2014). Infants intuitively analyze the statistical patterns in the speech sounds they hear to enable them to distinguish words in order to learn language (Saffran, 2003). Infants have an approximate number awareness that enables them to distinguish different small quantities, and toddlers are beginning to comprehend number principles such as one-to-one correspondence (Mix, Huttenlocher, & Levine, 2002). Infants and toddlers are also keenly responsive to what they can learn from the actions of people and the words they hear. They pay attention, for example, to cues indicating that an adult is communicating with them—such as eye contact, infant-directed speech, and using their names—and then tune in to what the adult is saying and referring to (Csibra, 2010). The committee concluded that, to an extent not earlier recognized, learning begins from birth and provides the foundation for learning that follows.

Such a conclusion may seem surprising to practitioners who work with infants and toddlers because these achievements are not transparent in their behavior. Instead, very young children often seem distractible, driven by emotion, and impulsive, and consequently adults easily underestimate their cognitive abilities. Yet the astonishing growth of language, infants’ use of pointing and gestures to get an adult to look at an interesting object, and babies’ use of an adult’s emotional expressions to determine whether unfamiliar objects are safe or dangerous are among the hallmarks of a rapidly developing mind at work.

How, then, should practitioners who work with very young children use this knowledge? One recommendation of the committee is to recognize that the thinking of infants and toddlers is far more inquisitive and conceptual, and less egocentric, than traditionally believed. Using an abundance of child-directed language when interacting with them by labeling, putting into words what people are feeling or objects are doing, and narrating the child’s ongoing experience of discovery and problem-solving are among the ways that adults provoke early cognitive growth (see box *From Transforming the Workforce*). In addition, engaging in imitative play, categorization (sorting) and counting games, creating “what would happen if” informal experiments of physical causality, and responding to the child’s curiosity about unexpected events enlists social interaction into new learning. With research showing that the amount of child-directed speech by adults to infants was associated with their vocabulary size at 2 years old (Weisleder & Fernald, 2013), and that parents’ spontaneous “number talk” (e.g., counting objects, references to time) from 14 to 30 months was associated with children’s number knowledge at 46 months (Levine, Suriyakham, Rose, Huttenlocher, & Gunderson, 2010), such experiences with caregivers provide the foundation

From Transforming the Workforce

Consider, for example, a parent or other caregiver interacting with a 1-year-old over a shape-sorting toy. As they together are choosing shapes of different colors and the child is placing them in the appropriate (or inappropriate) cutout in the bin, the adult can accompany this task with language that describes what they are doing and why, and narrates the child’s experiences of puzzlement, experimentation, and accomplishment. The adult may also be using number words to count the blocks as they are deposited. The baby’s attention is focused on the constellation of adult behavior—infant-directed language, eye contact, and responsiveness—that signals the adult’s teaching, and this “pedagogical orientation” helps focus the young child’s attention and involvement. The back-and-forth interaction of child and adult activity provides stimulus for the baby’s developing awareness of the adult’s thinking (e.g., she looks at each block before commenting on it or acting intentionally on it) and use of language (e.g., colors are identified for each block, and generic language is used to describe blocks in general). In this interaction, moreover, the baby is developing both expectations for what this adult is like—safe, positive, responsive—and skills for social interaction (such as turn taking). (Institute of Medicine and National Research Council, 2015, p. 103)

for the development of cognitive skills that children will use throughout life. These experiences also provide a foundation that subsequent educators can build upon.

Because early learning is rapid and cumulative, young children benefit from continuity in their learning experiences over time. This continuity occurs when adults in various roles and settings communicate with each other about the child’s progress and characteristics and treat them with sensitivity to their developing capabilities and according to best practices in early education.

Learning Is More Than Just Cognitive Skills

The committee writing *Transforming the Workforce* devoted considerable attention to the science of early learning. In addition to the studies of early cognitive development described above, the report discussed extensive research on the concept knowledge that children acquire for learning specific subjects, such as mathematics and language, as they enter school.

From the outset, however, the committee noted that learning is more than just acquiring cognitive skills (see Figure 1). In addition, learning includes (a) learning skills and competencies that help children acquire further understanding in formal and informal settings, (b) socioemotional development that supports

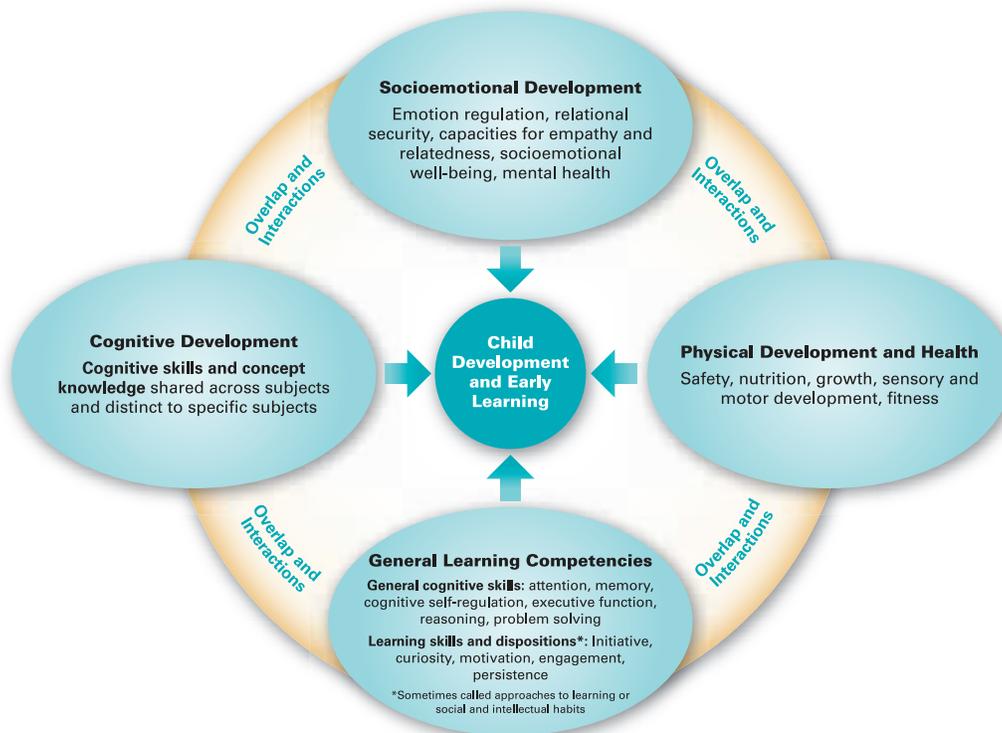
emotional well-being and the social skills for learning with other people, and (c) physical development and health that provide essential resources to early learning.

LEARNING SKILLS AND COMPETENCIES

Early learning is fueled by curiosity, engagement in learning challenges, persistence in problem-solving, the initiative to pose and explore alternative approaches, strategies of reasoning and problem-solving, self-confidence, and self-regulatory capacities that enable children to manage their attention, thinking, and emotions in learning activities. These characteristics have been labeled “noncognitive skills” by Heckman (2007, p. 13250) and others to distinguish them from strictly cognitive skills, but the committee instead chose the term “learning skills and competencies” to describe what they are and their importance to early learning. Beginning in infancy, when the baby’s “mastery motivation” denotes the persistence, focus, and curiosity accompanying exploration and problem-solving (Wang & Barrett, 2013), educators and researchers have long recognized that these competencies are significant contributors to early learning and to differences in academic success.

Many of these learning competencies involve self-regulation, which has been studied under the concept of “executive

FIGURE 1. **The Organization of Early Learning**



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functions” (Best & Miller, 2010). Executive functions are a collection of competencies that include developing working memory, growing cognitive flexibility, and developing capacities for inhibiting an initial response to consider alternative responses that might be better. These skills support learning and academic achievement in many ways throughout childhood and adolescence, such as by helping children to make reasoned rather than impulsive judgments and to consider alternative perspectives. Executive functions are based in brain regions that have a long maturational course—beginning in infancy and extending to early adulthood—but they develop most rapidly between the ages of 3 and 5 years. This means that most children at school entry are beginning to think more flexibly, use memory strategies, and focus their attention and thinking better than at younger ages (although they still have a long way to go). By contrast, infants and toddlers have very limited capacities for self-regulation, and thus require the support of caregivers to manage their attention, feelings, and behavior (Thompson, 2009).

Self-regulatory skills, together with other learning competencies, also develop in the context of children’s relationships with adults who support their learning. As described below, their enthusiasm for the child’s problem-solving, confidence in the child’s success, and cognitive probes help to strengthen the child’s approaches to learning. Viewed in this manner, educators are important not just for the cognitive skills they promote but also the learning skills they help to inspire and support.

SOCIOEMOTIONAL DEVELOPMENT

Early learning also depends on growth in a variety of socioemotional skills that support emotional well-being and social competence in learning settings. As described in the report, these skills include social awareness (i.e., social and emotional understanding), self-awareness (including self-confidence and knowledge of one’s strengths and limitations), relationship skills, self-management, and responsible decision-making. Learning competencies and socioemotional skills thus overlap, as one would expect them to. Self-regulatory skills, for example, are as important to children’s successful interactions with others in classroom activities as they are to children’s capacities to focus their attention and thinking.

The importance of socioemotional skills is underscored by how much early learning is social and relational in nature. Early in life, infants and toddlers require the relational support that keeps them focused and persistent in learning activities because their self-regulatory skills are so limited. With increasing age, socioemotional skills are essential to the ability to function successfully in classrooms and other group learning activities because most early learning is social in nature. The importance of these skills is also reflected in considerable research reviewed in the report showing that early behavioral and emotional problems impede early learning and pose further risks to school adjustment, academic achievement, and long-term educational and vocational success in adolescence and adulthood.

PHYSICAL DEVELOPMENT AND HEALTH

Early learning also depends on physical development and physical well-being, which includes the safety of the physical and built environments in which children live, the nutritional adequacy of the child’s diet, child health and fitness, and adequate health care if problems arise.

Unfortunately, some of the strongest evidence for the importance of physical health to early learning derives from studies of children living in difficult circumstances. As described in the report, considerable research documents the poorer learning and academic performance associated with compromised health, food insecurity, nutritional inadequacy, and limited physical activity in childhood. The committee described how early care and education settings can be important avenues for ensuring that children receive regular immunizations as well as health, vision, dental, and behavioral screening to identify children with special needs. Early education settings can also be forums for health education (for families as well as children) and sources of referrals to community health agencies.

Relationships Are Central to Early Learning

The skills and competencies essential to early learning develop in a relational context. The committee writing *Transforming the Workforce* agreed with the *Neurons to Neighborhoods* committee that nurturing relationships are the “active ingredients” of learning and healthy development. What was new in the 2015 report was the recognition that high-quality, positive learning environments are also important to enable adults to develop secure, responsive relationships with children, and to provide support to the adults who work in these settings.

The importance of relational support to early learning is illustrated by research on parent-child attachment, which shows how relational security promotes the child’s confidence and competence at exploration, supports self-regulation, buffers stress, and enables children to learn from the sensitive guidance provided by their caregivers (Thompson, 2013). Other research summarized in the report profiled how young children develop an awareness of their strengths and limitations and acquire self-esteem through the evaluations of those who care for them and how those evaluations are conveyed. Social interaction is also a forum for the growth of cognitive skills, such as the storybook reading and counting games that provide initial foundations for understanding language and number. As children mature, of course, the activities they share with parents that promote learning also evolve: conversations become longer and more complex, items are measured and sorted into groups of specific quantities, and shared problem-solving becomes more dogged and creative. In these ways, cognitive skills and learning competencies are shaped by social interaction.

Young children also develop emotional connections to caregivers and educators outside of the home, and these relationships also support early learning. Considerable research shows that children achieve more in learning environments in which they



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Infants and toddlers have very limited capacities for self-regulation, and thus require the support of caregivers for support to manage their attention, feelings, and behavior.

have positive relationships with the adults in those settings. In addition to creating a positive climate for learning, these teachers encourage the child's effort, persistence, and mastery through verbal comments and by working alongside the child, especially as they engage in open-ended conversations about the child's interests and experiences. Children who develop positive relationships like these are more excited about learning, more enthusiastic, and more self-confident.

As the report notes, however, many early learning environments are not well designed nor well resourced for promoting these kinds of positive child-teacher interactions, especially in settings for young children. Early learning environments can be deficient because of the high number of children (and their age range) in relation to the number of adults, the limited size and quality of the environment, and the poor availability of developmentally appropriate materials to stimulate children's thinking. In addition, the committee noted that early childhood educators are frequently under stress, with high rates of depression, emotional exhaustion, burnout, and physical illness as the result. The educator's stress can directly impact the quality of interactions with a child. In one study, for example, researchers measured the depressive symptomatology of 761 home- and center-based care providers, and they found that depression was linked to higher levels of behavior problems in the 3-year-olds in their care owing, in part, to the poorer quality of care in those settings (Jeon, Buettner, & Snyder, 2014). Understanding the significance of children's relationships with the adults who educate them, therefore, requires appreciating how other factors within the learning environment, as well as demands on the adult, can make those supportive relationships easier or more difficult to develop. Stress for teachers, as well as for children, can be an important problem.

Chronic Stress Impedes Early Learning and Healthy Development

One of the significant discoveries about early learning during the past 15 years reflects a sad reality in the lives of young children. Chronic stress undermines early learning and healthy development, the committee reported, because of its biological consequences for developing children. Concerted research on this issue in recent years coincides with the experience of early educators that increasing numbers of young children are appearing in their classrooms showing behavioral signs of stress, trauma, and living in adversity (Thompson, 2014).

What kinds of experiences constitute chronic stress for children? Poverty is the most prevalent and best studied, in part because it incorporates multiple stresses associated with food insecurity, housing instability (and sometimes homelessness), parental depression and anxiety, poor child care and schools, and environmental toxins and other dangers that may endure and cumulate. In 2013, nearly half the children under 3 years old in the United States lived in families in poverty or near-poverty conditions (Jiang, Ekono, & Skinner, 2015). Other sources of chronic stress include child abuse and foster care. These experiences constitute readily recognized experiences of "toxic stress." But the committee noted that other forms of chronic stress for young children might not be so easily recognized as severe, such as parental depression or continuing marital conflict in the home. That young children respond to these conditions with heightened stress underscores that they experience certain circumstances as stressful that an adult would not regard as severe, but which are significant to children because they involve the withdrawal or denial of nurturing support.

Chronic stressful conditions have biological consequences that help to account for their immediate and long-term behavioral effects. Prolonged activation of physiological stress systems, especially in the absence of supportive relationships, alters the neurocircuitry of those systems and thus becomes "biologically embedded" in their development. Sometimes this causes these systems to become hyperreactive to perceived threats; in other cases, stress reactivity becomes blunted or underresponsive; in either case, stress responding becomes poorly regulated. Chronic stress also creates dysregulation of the immune system, which increases the child's vulnerability to infections and chronic diseases. Furthermore, the chronic output of stress hormones has downstream effects on other brain systems that regulate stress reactivity. These include the prefrontal cortex (the seat of executive functions that manage self-regulation and cognitive flexibility), amygdala (emotion activation and regulation) and hypothalamus (multiple motivational systems). One study reported, for example, that preschool children growing up in poverty had lower volumes of gray matter, which is tissue that is important to information processing, especially in brain areas relevant to cognitive reasoning and self-regulation (Hanson et al., 2013). More generally, the continuing "wear and tear" on biological systems resulting from chronic stress contributes to

the well-known association between early chronic stress and higher rates of health and mental health problems.

These biological effects have important consequences for early learning and development, according to the committee. Young children who are hyperreactive to threat may show greater reactivity and poorer self-control when social or emotional challenges ensue in the learning environment. Because of the brain areas affected by stress hormones, moreover, children experiencing chronic stress may have difficulty with self-regulation, language, and with maintaining attention and cognitively focusing on learning activities. Thus persistent stress is likely to undermine many of the cognitive skills and learning competencies on which cognitive growth depends and reduce the emotional well-being that children need to devote themselves to learning activities (Blair & Raver, 2012). It is thus not surprising that children in these conditions frequently fall behind their peers.

Young children's vulnerability to chronic stress and its biological and behavioral consequences underscores, therefore, the committee's attention to the associations between stress, learning, and early mental health. For many children, the influence of chronic stress undermines success in learning activities and contributes to the development of behavior problems that further erode classroom achievement. Consistent with this view, the committee summarized studies indicating that socioemotional and self-regulatory problems are frequently cited by early educators as common impediments to children's learning and school readiness. In addition, there have been significant advances during the past 15 years in documenting that even very young children show evidence of anxious and depressive symptomatology, behavioral and conduct problems, traumatization and posttraumatic stress, and other serious psychological problems (Egger & Emde, 2011). Taken together, understanding early learning requires appreciating how chronic stress constitutes a fundamental impediment to academic success and also poses significant risks to early mental health that also undermines children's learning and well-being. This is one reason that many early educators receive training in understanding the effects of early adversity on children's behavior and are establishing consultations with early childhood mental health specialists who can assist them when needed.

Fortunately, the support of close relationships can buffer stress for young children (and, indeed, for people of all ages). There has been longstanding research interest in the benefits of social support for coping with stress, and the committee noted that this work has recently been complemented by human and animal studies of the biological effects of social support on stress reactivity. These studies show that social support helps to reduce the reactivity of physiological stress systems and may activate biological systems that promote more effective coping and social bonding (Hostinar, Sullivan, & Gunnar, 2014). Taken together, these findings show that the experience of having someone "on your side" when facing difficulty can have emotional and biological benefits that aid effective coping, and this appears to be true for young children as it is for adults.



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Young children develop emotional connections to caregivers and educators outside of the home, and these relationships also support early learning.

Biology Continuously Interacts With Environment to Guide Learning and Development

The committee's summary of the effects of stress and social support on children's learning provides further evidence for the influence of early experience on brain development. The brain incorporates experience into its developing architecture whether those experiences are stressful or supportive, and new experiences can further alter the developing brain.

The continuous and adaptive interaction between biology and environment is a theme in *Neurons to Neighborhoods* that is also present in *Transforming the Workforce*. This theme led the earlier report to conclude that the debate over the relative importance of nature or nurture is "overly simplistic and scientifically obsolete" (NRC & IOM, 2000, p. 6) because biology and environment are each important and indissociable. The 2015 report identified, however, several scientific advances in understanding the interaction of biology and environment during the past 15 years that are noteworthy.

First, advances in understanding "gene-environment interplay" help underscore how inseparable are the influences of genetics and environment. Contrary to traditional views that the effects of heredity are immutable and direct, contemporary studies of gene-environment interaction and epigenetics show that how heredity is expressed in behavior depends significantly on environmental influences. The most groundbreaking perspective comes from the emergent field of behavioral *epigenetics*, which shows that environmental conditions can alter gene expression—that is, whether genes become activated (and thus influential) or deactivated (and thus uninfluential) in behavior and development. Thus even though DNA never changes, its expression can change. There is still much to be learned about epigenetic processes, but current research reviewed by the committee indicated that stress

is one of the most potent environmental conditions provoking epigenetic changes in gene expression in childhood.

Second, there are individual differences in how susceptible people are to environmental influences. Some children are dramatically affected by environmental adversity or support: they flourish when conditions are positive, but are significantly undermined when conditions are bad. By contrast, other children appear to be less affected by environmental adversity or support—they carry on fairly consistently in different circumstances. In the popular media and in some professional contexts, these children are distinguished as “orchids” (thriving under positive conditions but wilting under adversity) or “dandelions” (neither benefitting nor hindered significantly by different conditions). The reasons that children differ in this way are complex and may arise because of early experiences, temperamental variability, genetic predispositions, or a combination of these. Taken together, however, research suggests that not all children are affected in the same way by the same environmental circumstances.

What does this mean for early learning? It is too soon to derive strong conclusions, but these discoveries suggest that the impact of genes and environment in the classroom are variable. Learning activities will have different impact on children who differ in their genetic characteristics, but these activities also constitute the environment in which these genes are expressed. And a child who wilts in adversity may not simply be dispositionally vulnerable but instead the one who is prone to thrive if conditions become more supportive.

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Conclusion

Transforming the Workforce and *From Neurons to Neighborhoods* were written 15 years apart but with complementary agendas: each committee was asked to summarize current scientific understanding of early learning and development and explain its implications for policy and practice. The results are descriptions of the significant influences on early development that build on each other and show the remarkable growth in developmental science in the interim. Most important, the conclusions provided by each committee have significant implications for equipping the early childhood workforce with the knowledge and skills needed to seamlessly support learning from birth through childhood. Each committee's recommendations for changes in public policy and professional practice offer hope that, in the future, society's support for healthy early development may reflect the best knowledge of the influences that guide children's growth in a positive direction.

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