

Key Findings and Implications of the Science of Learning and Development

The past few decades have seen an explosion of knowledge about how children grow and develop, how they become learners, and the factors that nourish or hinder their growth into adulthood. A convergence of research across many scientific disciplines—including neuroscience, epigenetics, early childhood, the social sciences, psychology, the science of adversity, strength-based approaches to human thriving, and the learning sciences—paints a much more dynamic and optimistic picture of human development than once existed.

Today we know that the expression of our genetic makeup, and the realization of our potential, are not fixed at birth. A significant part of brain development happens after we are born in direct response to the experiences, relationships, and environments we encounter from the prenatal period all the way into adulthood. This fundamental principle of malleability or plasticity—the amazing ability of our neural connections to strengthen and grow as we interact with the world around us—underscores the chance for all children to reach their full potential.

This research offers valuable insights for educators, caregivers, and policymakers, as well as reinforcement of the best practices that many educators and system leaders make part of their daily practice. But this knowledge remains distressingly underused at scale. Understanding this knowledge, research, and evidence—and designing schools and instruction based on it—could solve longstanding, seemingly intractable social and learning problems.

- I. Human development depends upon the ongoing, reciprocal relations between individuals' genetics, biology, relationships, and cultural and contextual influences.
 - Human development occurs within nested, interlinked micro- and macro-ecological systems that provide both risks and assets to development and affect development both directly and indirectly.
 - Epigenetic adaptation is the biological process through which these reciprocal
 - individual-context relations create qualitative changes to our genetic makeup over time, both within and across generations.
 - Genes are chemical “followers,” not the prime movers, in developmental processes; their expression at the biological level is determined by contextual influences.
 - The development of the brain begins prenatally and continues in one developmental continuum well into young adulthood. Opportunities for change, intervention, and growth exist across the developmental continuum, with particularly sensitive periods in both early childhood and adolescence.
 - Developmental systems theory and associated dynamic systems mathematical models provide a holistic, contextualized framework within which to integrate diverse, field- specific scientific knowledge, enabling a deeper understanding of the developing brain and whole child in context.
 - Intergenerational transmission is rooted in biological and social processes that begin before a child is born. Preventing the negative impacts of adversity can prevent the transmission of adversity and its many risks to development to future generations. Conversely, building individual and environmental assets can promote the intergenerational transfer of adaptive systems and opportunities.

- II. Each individual's development is a dynamic progression over time.
 - The human brain is a complex, self-organizing system.
 - Neural plasticity and malleability enable the brain to continually adapt in response to experience, which serves as a “stressor” to brain growth across development.
 - Each individual's development is non-linear; has its own unique pacing and range; features multiple diverse developmental pathways; moves from simplicity to complexity over time; and

includes patterns of performance that are both variable and stable.

- Whole child development requires the integration and interconnectivity—both anatomically and functionally—of affective, cognitive, social, and emotional processes. Though these processes—particularly cognition and emotion—have historically been dichotomized, they are inextricably linked, co-organizing and fueling all human thought and behavior.
- The development of complex dynamic skills does not occur in isolation; it requires the layering and integration of prerequisite skills, as well as the influence of contextual factors.
- Inter- and intra-individual variability in skill construction and performance—both of which are highly responsive to contextual influences and supports—is the norm. The optimization of development requires an understanding of both stability and variability in growth and performance.

III. The human relationship is a primary process through which biological and contextual factors mutually reinforce each other.

- The human relationship is an integrated network of enduring emotional ties, mental representations, and behaviors that connect people over time and space.
- Attachment patterns are formed through shared experiences of co-regulation, attunement, misattunement, and re-attunement. Though important in shaping future relationship patterns, early patterns remain open to change as children re-interpret, appraise, and re-appraise past experiences in light of new ones.
- Developmentally positive relationships are foundational to healthy development, creating qualitative changes to a child's genetic makeup and establishing individual pathways that serve as a foundation for lifelong learning and adaptation.
- Developmentally positive relationships are characterized by attunement, co-regulation, consistency, and a caregiver's ability to accurately perceive and respond to a child's internal state. These types of relationships align with a child's social-historical life space and provide protection, emotional security, knowledge, and scaffolding to develop age-appropriate skills.
- The establishment of developmentally positive relationships can be intentionally integrated into the design of early care and educational settings, practices, and interventions.

IV. All children are vulnerable. In addition to risks and adversities, micro- and macro-ecologies provide assets that foster resilience and accelerate healthy development and learning.

- Children's development is nested within micro-ecological contexts (e.g., families, peers, schools, communities, neighborhoods) as well as macro-ecological contexts (e.g., economic and cultural systems). These contexts encompass relationships, environments, and societal structures.
- Adversity, through the biological process of stress, exerts profound effects on development, behavior, learning, and health.
- Resilience is a common phenomenon wherein promotive internal and external systems integrate to facilitate the potential for positive outcomes, even in the face of significant adversity. As no two children draw from the same combination of experiences and supportive resources, resilience pathways are diverse, and yet can lead to equally viable and complex adaptation and ultimately, well-being and thriving.
- Environments and societal structures include the differential allocation of assets, risks and belief systems that legitimate or ignore the impacts of privilege. While factors such as poverty and institutional racism makes poor outcomes more likely, family and community assets must be recognized, as they can protect children from short- and long-term negative consequences.
- Adult buffering can prevent and/or reduce unhealthy stress responses and the resulting negative consequences for children. As such, building and supporting adult capacities are critically important priorities.
- Early care and educational settings that provide developmentally rich relationships and experiences can buffer the effects of stress and trauma, promote resilience, and foster healthy development. Meanwhile, developmentally unsuitable and/or culturally incongruent contexts can exacerbate stress, hinder the reinforcement of foundational competencies, and impel maladaptive behaviors.

- V. Students are active agents in their own learning, with multiple neural, relational, experiential, and contextual processes converging to produce their unique developmental range and performance. This holistic, dynamic understanding of learning has important implications for the design of personalized teaching and learning environments that can support the development of the whole child.
- Diverse scientific fields converge to describe the holistic, complex, dynamic, contextualized processes that describe how children develop as learners.
 - A powerful organizing metaphor through which to understand the dynamic interrelationships governing children’s development and knowledge and skill construction is that of the “constructive web.”
 - Key factors that affect learning are internal attributes (including prior knowledge and experiences; well-developed habits, skills, and mindsets; and motivational and metacognitive competencies) and critical elements of the learning environment (including positive developmental relationships; environmental conditions for learning; cultural responsiveness; and rigorous instructional and curricular design).
 - Foundational skills such as self-regulation, executive functions, and growth mindset lay the groundwork for the acquisition of habits skills and mindsets including both higher- order skills (e.g., agency, self-direction) and domain-specific knowledge.
 - Motivation and metacognition are important, inter-related skills for effective learning. These competencies enable and encourage students to initiate and persist in tasks, recognize patterns, develop self-efficacy, evaluate their own learning strategies, invest adequate mental effort to succeed, and intentionally transfer knowledge and skills to solve increasingly complex problems.
 - Instructional and curricular design can optimize learning. Together, well-scaffolded, engaging, relevant, and rigorous content; personalized contextual supports in multiple modalities; and mastery-oriented pedagogies embedded in well-designed, interdisciplinary projects can balance what students already know with what they need and want to know.
 - Interpersonal and environmental conditions for learning (CFL) impact learning processes both directly and indirectly through their effects on cognition (e.g., cognitive load), student and teacher stress, and the relational dimensions of learning (e.g., attunement, trust). High-support conditions that recognize students’ individual starting points and strengths can facilitate deeper learning while increasing developmental range, performance, and mastery.
 - Culture is a critical component of context. Cultural competence and responsiveness can address the impacts of institutionalized racism, discrimination, and inequality; promote the development of positive mindsets and behaviors; and build self-efficacy in all students, particularly those from culturally and linguistically diverse backgrounds.
 - Skill development occurs in all ecologies, cultures, and social fields. Next to the family, early care and education settings are the most important social contexts in which early development unfolds.
 - Research and development (R&D) efforts can be enriched, and progress accelerated, by employing dynamic systems analysis techniques and rapid-cycle improvement science methodologies to identify positive variation in developmental pathways and apply this knowledge at scale.
 - The design of education and other child-serving systems—and surrounding policy environments—cannot bet on the resilience of children alone. Rather, such systems must capitalize on the opportunities presented by the translation of developmental science to the design of contexts and practices, therein supporting a fully personalized approach to whole child development and the expression of human potential.
 - Dramatic improvements in outcomes and equity depend on public and political will. Sound policies to foster whole child development and practice must be grounded in rigorous science; implemented with quality; measured with an understanding of the formative progression of individual development; and adopted at scale, with cultural competence and equitable outcomes as explicit goals.

Children’s development and learning are shaped by many interacting factors – relationships, family and environmental contexts, curriculum and instruction – which come together to impact each child in a unique way. To support each child’s success and to achieve greater equity in both opportunity and outcomes, schools

must take a whole child perspective and personalize learning in ways that take these factors into account. This requires:

- I. **Conditions for learning that support student success along the developmental continuum:** These include supports for positive, trusting relationships; attachment and emotional connections; physical and emotional safety, and a sense of belonging and purpose.

Key insights from the science of learning and development and from educational research suggest the following principles for practice in this domain:

1. School and classroom structures should be designed to create and support **strong attachments and positive, long-term relationships** that provide academic and social-emotional support for cultivating developmentally-appropriate skills, emotional security, resilience, and student agency.
 2. Schools and classrooms should be developed as culturally responsive learning communities in which all children feel a sense of **physical and psychological safety and belonging** and teachers engage in practices that help them **know their students well** so that they can respond to children's specific needs, interests, readiness for learning, and opportunities for growth and mastery.
 3. School practices should be designed to **strengthen relational trust** and promote **cultural competence** among educators, school staff, and families to provide deeper knowledge about children and greater alignment between the home and school.
- II. **Curricular designs and instructional strategies that support academic capacity, competence, efficacy, motivation, metacognitive skills, and mastery.** These designs feature well-scaffolded instruction and ongoing formative assessment that support personalized and collaborative learning, take students' prior knowledge and experiences into account, and provide the right amount of challenge and support on relevant and engaging learning tasks.

In the domain of instruction and curricular design, the science of learning and development suggests the following principles for practice:

1. Teaching should **build on children's prior knowledge and experiences** to utilize existing expertise, avoid cognitive overload, and scaffold future learning effectively as it expands to new areas of content and skills. Given what each child is ready to learn, teachers should structure appropriately challenging activities that balance what a child already knows with what he wants and needs to learn.
 2. Teaching should **support engagement, motivation and understanding**, by designing relevant, problem-oriented tasks that combine explicit instruction about key ideas – organized around a conceptual map of the content domain being taught – with well- designed inquiry opportunities that tap multiple modalities for learning.
 3. To enable learning that is transferable and supports a growth mindset, teaching should be designed to develop **metacognitive thinking, agency, and self-efficacy**, including opportunities for self-direction, goal-setting and planning, and formative assessment with regular opportunities for feedback, reflection, and revision of work.
- III. **Support for the intentional development of social, emotional, and cognitive skills, mindsets, and habits.** These include self-regulation, executive function, intrapersonal awareness and interpersonal skills, as well as growth mindsets and a sense of agency that support resilience and productive action;

The science of learning and development suggests the following principles for practice:

1. Schools and classrooms should provide **regular opportunities to integrate social, emotional, and cognitive skills** (e.g., intrapersonal and interpersonal awareness, cooperation, conflict resolution) into academic curricula and throughout the day.
2. Students should receive guidance and support to **develop foundational skills, habits, and**

mindsets that promote perseverance, resilience, agency, and self-direction (e.g., executive function, self-regulatory routines, stress management, growth mindset).

3. **Behavior supports should foster belonging and aim to be educative and restorative rather than punitive** (i.e., teach behaviors, encourage students to take responsibility, make amends, and proactively contribute to their community).

- IV. **Structures that reach beyond the classroom to provide systems of academic and social support**, including personalized supports that respond to students' needs and address the effects of adversity.

To address these needs, the science of learning and development suggests the following principles for practice:

1. Schools should create a collaborative **multi-tiered system of supports**, based on a shared developmental framework uniting staff, families, and support providers as they address learning barriers and meet student needs both in and out of the classroom.
2. Schools should develop **internal student support structures** (e.g., counseling and student support teams) and coordinate **access to integrated services** (including physical and mental health and social service supports) that enable children's healthy development, via on-site supports and partnerships with community providers.
3. **Extended learning opportunities should be designed to support personalized instruction and mentoring** that nurture positive developmental relationships, support mastery learning, and close achievement gaps.