What the Science of Learning and Development Now Tells Us

A Translational Working Paper: Updated Based on the 2023 Review of Research in Education and Key Documents Published 2020–2023

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Author's Note

This working paper represents my own synthesis and perspective, drawing on collaborative scholarship I have been part of building since 2016 — including peer-reviewed papers in *Applied Developmental Science**, the 2020 SoLD Alliance translational paper (chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://soldalliance.org/wp-content/uploads/2021/12/SoLD-Science-Translation_May-2020_FNL.pdf), and co-edited volumes 47 and 49 of the* *Review of Research in Education**. My scholarly grounding is in historical sociology, and that shapes how I read this evidence: with attention to context, power, and the systems that have long determined who gets to learn and thrive. The interpretations, emphases, and judgments here are mine alone. I employed Google Gemini, Claude, and ChatGPT to assist with synthesis, summarization, and drafting refinement; I critically reviewed all AI products. I offer this as a translational working paper — inviting engagement, correction, and dialogue as the field continues to develop. A fuller account of the scholarly lineage this paper draws on appears in "About This Working Paper" at the end of this paper. *

All children can learn and thrive under the right conditions. Many people who work with children believe this to be true. But the science of learning and development shows that this idea is more than just a belief. It's grounded in scientific findings from many disciplines and, more importantly, it's a foundation upon which we can design, build, and support environments for learning and development, as well as support systems, so that every young person can achieve their full potential. These scientific findings also indicate how unsupportive practices and aversive environments hinder the realization of this human potential.

In recent years, the science of how young people learn, develop, grow, and come to master complex skills has advanced substantially. This knowledge is critical for the education and development of all children. Still, it is especially powerful in creating educational and social equity, where we have fallen short in the past. We may, for example, believe that all children can learn, but our educational practices and policies too often reflect the opposite, including marginalizing learners who don't respond to "traditional" K–12 educational approaches.

When we understand the complexities of human development, however, we can see that every young person—no matter their background, income, racial identity and status, race, gender,

sexual orientation, learning strength, social, emotional, and cognitive strengths and experiences they bring, family history and culture or genetic and epigenetic makeup—is capable of realizing their strengths and abilities and intelligence, and that the science of learning and development can help show us why and how. This hopeful story must inspire us to work harder and smarter to help each young person reach their potential so they can thrive in school and beyond. We owe our children no less.

Overview

This updated synthesis draws on an extensive and growing body of interdisciplinary research to document what science now tells us about how young people learn, develop, and thrive—and what those findings mean for the educators, families, policymakers, and community leaders who shape the conditions of young people's lives. It is written especially for people working to advance opportunity, equity, and development for all young people, in all the settings where they grow.

- **Every child, no matter their background, has the potential to succeed in school and life.** Despite current education practices—particularly in K–12 schools—that were often founded on the idea that some individuals had limited potential (most often singled out by race or class), these studies confirm that everyone can have a path to positive development and successful learning. Education systems can support success by being attuned to children's diverse needs, interests, and abilities, and to the fact that children learn 24/7 across all the environments they experience.
- **No two young people learn in precisely the same ways.** Brain development and learning do not proceed in a straight line, and neural connections uniquely zig and zag as they are created. Strong relationships with adults and peers, individualized supports, and well-designed environments all help ensure that each young person's own zig-zag learning and development move forward toward success.
- **Culture matters—culture is dynamic, not fixed.** Culture both frames learning and provides resources to support learning. Individuals create and enact culturally shaped contexts as they use and transform cultural practices shaped by prior generations.
- **Context matters—and contexts are culturally infused.** Learning and development are shaped by the many environments young people inhabit: their families, schools, neighborhoods, and communities. There is no culturally neutral environment. Every context carries individual and group histories, practices, and ways of making meaning that shape what young people learn, how they experience learning, and who they understand themselves to be.
- **Social relationships matter.** Although learning is embodied in individually constructed pathways, it is also social and socially situated. Peer learning and support, as well as adult learning and support, affect learning and development, and people learn and think in languages and with grammars that they both inherit and refine.

- **Children's ability to learn is strongly intertwined with their social, emotional, cognitive, and physical needs.** This concept is obvious to any teacher who has tried to teach hungry, anxious, or distressed children. To be successful, education systems must consider and address the full range of children's social, emotional, cognitive, and physical needs.
- **The environments, experiences, and cultures of a young person's life are more influential than their genes.** In the past—and even today in many places—a child's genes have been treated as their destiny. But genetics turns out to be less important to a child's development than epigenetics—the science that studies which genes are activated by environments and how experiences influence the ways genes are expressed.

How We Got to the Current Educational System

In the nineteenth-century United States, public education was primarily designed as a tool for nation-building and social cohesion. The role of schools was to acculturate immigrants and instill shared White, Anglo-Saxon, Christian, republican values and moral discipline. As the Industrial Revolution gained momentum, schools assumed a new economic role: facilitating the transition from agrarian life to the factory floor. This era introduced a "hidden curriculum" of punctuality and obedience, using school bells to mimic factory whistles and training a workforce to operate by the clock rather than the seasons.

By the twentieth century, this had matured into a "factory model" of education—one predicated on the myth of the "average" person. Drawing on the logic of Scientific Management, schools sorted children along a bell curve, delivered standardized curricula for interchangeable parts, and grouped students in age-based cohorts rather than by developmental need. The system focused on content memorization and instruction-following rather than the development of individual talents. If 30 percent of students moved on to college, that was considered a good result. By prioritizing industrial utility over human potential, it locked out those who did not conform to a narrow, racialized average—and it used the science of the time to justify doing so.

The public education system of the twentieth century wasn't designed to unleash the potential of every young person. Instead, it was designed, in most cases, to ration educational resources inequitably, disregard the importance of diversity, and elevate a few over the many. Schools disproportionately benefited students from privileged backgrounds and were used to "weed out" those who did not fit the mold. This was especially detrimental to young people of color and others who were underserved. The result is that generations of children were locked out of early childhood education, equitable K–12 education, higher education, and adult success—all because they fell outside a restrictive average or were not born white and male. Our communities, our workforce, and our national leadership are poorer for losing this untapped potential.

Many educators are already reorienting their work to reflect a different truth. Some understand it reflexively; others are guided by evidence-based approaches that serve a wide range of students. But the scientific information that supports these efforts has not been widely shared,

valued, or institutionalized. Too many capable and dedicated educators are still being asked to operate within a system built for a different century and a different economy.

The Science of Learning and Development

Key findings from the science of learning and development can help us transform learning, schools, community, learning opportunities, and education systems. Learning and development are products of dynamic human and organizational systems; consequently, the findings overlap and should be read and addressed together. These findings reflect an underlying understanding that human development is actively self-organized through experience, human interaction, task participation, meaning-making, and learning, rather than determined by any single factor.

Every Child Has Great Potential

There is no "bell curve" on human potential.

Every young person has great potential to learn and thrive under the right conditions. All children develop billions of neural pathways that can enable learning and positive development. These include multiple pathways to learning foundational knowledge and skills, at every stage of life, and to discovering multiple areas of talent and interest that create potential for fulfillment in school and in life.

Realizing this potential—finding and forming the integrated neural connections around complex knowledge and skills—depends chiefly on how we understand and support each young person's unique pathways and how we shape their experiences, environments, culture, relationships, and learning as a whole child.

The concept of genetic determinism—that an individual has a fixed capacity to learn and adapt, determined at the beginning of life—is a myth. Genes are chemical followers, and within each person, only a small portion of their genetic make-up is activated over the course of their lives. The validated, mainstream scientific literature of recent decades is in strong agreement that every young person has the potential to thrive—if adults are responsible for their learning and development, they challenge their own assumptions about who can learn and how to bring out abilities and talents in every child.

The Brain Is Highly Malleable

The ability to learn does not end, and adversity in life does not determine who a person can become.

The brain is highly malleable, from birth through adolescence and beyond.

The tissue that makes up a young person's brain is more easily changed than any other organ in the human body. It is constantly being shaped by experiences, environments, and relationships—both positively and negatively.

Neurological development and remodeling occur more regularly in humans and extend over longer periods than in any other mammal. These processes begin in utero and continue well into early adulthood—certainly past one's mid-twenties—and beyond. Learning also continues across the lifespan as individuals learn from experiences and make sense of them.

This malleability, which also reflects the biologically grounded and culturally supported capacity to make meaning, learn, and change, is more important than scientists of earlier decades recognized. Researchers previously thought that most development occurred only in the first few years of life. The science is much more encouraging: Lifelong learning can happen for virtually anyone under the right circumstances and with the right supports.

Two periods of heightened sensitivity and change are particularly important: from birth to approximately age 5, and during adolescence. During these times, a young person makes important progress, such as developing an identity and learning increasingly complex skills. But neurological development hardly goes quiet in between or after. Even in late adolescence, new experiences stimulate the creation of synapses in the brain—the connections that send signals between neurons—at a rate of hundreds per second.

Unique Pathways

Every young person follows their own unique pathway of learning and development.

All of us have unique neurological structures, genetic expression, backgrounds, and personal experiences. Because of this individuality, each of us has a unique, dynamic learning path. Just as no two children have the same interests, vulnerabilities, and personal strengths at any one moment, no two children will come to understand educational concepts in the same way or at the same time.

There is no such thing as an "average" learner. Children do not learn as uniform cohorts. Some children may acquire a specific skill only to lose it and relearn it later. Variability in and among children is the norm, not the exception.

Because of this new understanding, modern research has begun to put a premium on studying the individual rather than inferring from group averages. Empirical work using intensive longitudinal methods—including research applying the Bornstein Specificity Principle to executive functioning across grades 4 through 12—confirms that intraindividual developmental trajectories are distinct from group-level patterns, and that person-specific pathways cannot be reliably inferred from population averages (Yu et al., forthcoming). This can enable educators to see what works best for each learner and under what conditions.

At the same time, no one learns alone. Every learner's individual learning journey unfolds within—and is shaped by—the social contexts that surround it: the relationships in a

classroom, the presence of peers and friends, the guidance of teachers and mentors, the support of families, and the histories and cultures carried into every learning environment.

Context

There is no "normal" or "average" learner.

Experiences, environments, and cultures are the defining influences on development.

Just as our brains process information in unique ways, the experiences that shape us are at least equally unique across the breadth of our lives. Context operates on multiple interconnected levels—from the individual and family to the community and broader social systems. These systems can either enable or constrain learning, and practitioners play a vital role in creating conditions that counter systemic inequities.

We don't receive or process information in a vacuum. Our learning and development are deeply affected by our physical and emotional states, which are shaped by our cultures and contexts, including the influence of those with whom we have immediate contact, as well as external factors such as policies, norms, and structures that shape us and our contexts.

- We use the word context to describe how children's development is affected by experiences, environments, and cultures.
- Culture influences what and how people learn, and learning also shapes culture. Culture is dynamic—changing and experienced differently by individuals and families. A young person's culture shapes both the learning environments they encounter and how they engage with them.
- Culture also shapes how adults view children and, correspondingly, the deeply consequential choices they make in teaching and supporting them.

Nothing happens to the developing brain that is not contextualized. Recent scientific literature in the growing field of epigenetics shows that the view that potential and intelligence are merely inherited is both scientifically and biologically incorrect. Our environment, experiences, and cultural context determine which genes play a significant role in shaping our physical and psychological attributes.

Importantly, a supportive context can help children overcome negative experiences and develop resilience and a belief in their ability to succeed. Educators who understand the need to design and support positive contexts and a holistic, whole-child approach will be more successful in reaching and teaching all children, particularly those children least served by most current education systems.

Learning Environments Can Be Designed for Positive Development

Strong, trusting relationships are essential to learning and development.

The presence and quality of our relationships may have more impact on learning and development than any other factor. Indeed, relationships are the primary processes through which our biological and contextual factors are reinforced.

Emotion and cognition are inextricably linked, and one of the best ways to foster a positive context is to create opportunities for positive developmental relationships, both at home and beyond.

Educators' well-being and support systems are key to environments where young people can thrive. Supporting the adults who support learners amplifies student success.

Encouraging curiosity, active listening, and shared problem-solving helps young people engage responsibly and empathetically with others.

Positive relationships—supportive families, involved teachers, caring coaches, supportive peers—serve as the foundation for children's ability to adapt, establish good emotional health, foster social connections, and build the complex neural processes that make us resilient and effective learners.

The capacity of people to attune to and support others depends upon their own well-being and the support they, too, receive. Positive relationships are sustained not only by caring individuals but also by supportive environments and policies that nurture adult well-being and capacity to connect with young people and to care and sustain that care.

One way to see the power of relationships is to examine the limbic system, which is the learning center of our brains. It is exquisitely sensitive to experience and plays a role in regulating attention, focus, memory, and emotion. Two key hormones mediate the structure of this system: cortisol, which responds to stress, and oxytocin, released when we experience feelings of trust and love. In other words, love, trust, friendship, and mentoring can help reduce the damage that problems like poverty, discrimination, and anxiety cause in children's lives.

Education systems can support this positive development by fostering opportunities for children to build strong, trusting relationships that help them grow, develop identities, explore the world, and learn with positive reinforcement—and by providing adults with supports so they can attune to children's needs in a timely and supportive manner.

Relationships Ignite Development and Support Learning

Learning is fully embodied, relational, and interdependent—integrating mind, body, emotion, and culture in every experience.

Intentional integration accelerates learning. When learning connects across home, school, and community, it becomes consequential—it shapes who young people see themselves becoming and how they act in the world.

Despite common misconceptions, learning is a full-body experience, not something that happens only through academic experiences or only in our minds. We learn through our emotions and feelings, through engagement with others, through bodily motions, by examining objects in our hands or ideas in our minds, and by moving through time and space.

Neuroscience research—including the pioneering work of Mary Helen Immordino-Yang—shows that this integration runs even deeper: emotion is not separate from thought but is the very organizing force that makes learning meaningful and memorable. The brain's systems for reflection, self-understanding, and meaning-making depend on the integration of emotional and cognitive experience. Young people need time and space for inner life—for reflection, wondering, and narrative—not only structured activity.

In other words, the brain is nested in the body and shaped by the individual's mind—and all three are nested within a young person's physical, cultural, cognitive, and emotional environment. The brain grows in its ability to do complex things, such as reading, riding a bicycle, or developing resilience, as the structures become integrated and wired together.

Cognition and emotion have traditionally been regarded as separate. However, research in the science of learning and development over the last two decades shows that thinking, feeling, behavior, and social relationships are inextricably linked and work together to produce learning. Stress can have powerful effects on the developmental process, interfering with a child's confidence, motivation, and curiosity.

This integration is why children must be seen as whole people and taught holistically. Children need support in developing self-regulation and executive functioning. They must develop physical and psychological wellness to understand themselves and their relation to the world. Thriving is collective, not only individual: communities grow when learning systems nurture shared purpose and equity.

Our Brains Develop Higher-Order Knowledge and Skills by Integrating Social, Emotional, Academic, and Other Experiences

Human development is a progression, but not a linear one.

Just as children currently move up through grade school, we often think of learning as a linear process. But, in reality, learning and development look less like a straight line on a chart; instead, imagine an impressionistic painting. Up close, it might seem messy, with chaotic brushstrokes going back and forth. Children may learn skills and then may lose them. They may attempt certain concepts and fail, only to grasp them later. In other words, human development and learning are dynamic and context-dependent, not linear or unidirectional.

The brain grows, changes, and remodels as it develops, shaped by biological processes as well as by contexts encompassing its environments, experiences, relationships, and cultures. There is no pre-determined path from the relatively undifferentiated tissue in the infant

brain to the far more connected structures and neural pathways of the mature brain. Our education systems need to see development into maturity as a single developmental arc—a common picture that will be realized with great variability from person to person.

Each Child's Learning Builds on What Came Before

Meaning-making ignites the desire to learn.

Our brains are exquisitely biologically designed to filter, organize, and categorize the incoming stimuli from other people, places, and things—and from our and others' perceptions of, and sense-making about, the world around us. This constructive individual and collective process of meaning-making leads every human being to develop along a life path marked by an evolving understanding of themselves, people who matter to them, and the changing world around them.

Meaning-making is both individual and collective and occurs when people reflect on, bring order to, and make sense of new knowledge and experiences, enabling more effective learning, applying knowledge to new problems, and making better, more informed choices in the future.

Learners thrive when they can influence and reshape their environments, not only adapt to them. School experiences that are not designed to support sense-making may lead young people to develop the feeling they are "bad in math", or "not a good reader." On the other hand, well-designed and well-guided learning experiences can enable young people to apply their learning in productive and meaningful ways to real-world problems.

What makes learning stick—and transfer

Research on deeper learning and transfer helps us understand why the kind of meaning-making described here is so powerful. When young people develop genuine conceptual understanding—not just memorize facts, but truly grasp ideas across science, mathematics, history, literature, or civics—they build knowledge they can actually use. They can apply what they learn to new, unfamiliar problems. They can evaluate evidence and arguments they have never encountered before. And they carry this thinking with them far beyond the classroom.

This kind of deep understanding does not happen when learning is structured as simple transmission. It happens when young people have opportunities to actively explore, question, connect new ideas to what they already know, and work together to reason through complex problems.

Preparing young people for a complex and democratic world

Deep conceptual understanding is not just an academic goal—it is a civic necessity. Today's young people will navigate a world of competing claims, contested evidence, and complex collective decisions. Schools can play a vital role in helping them develop the dispositions and skills they need to participate meaningfully in that world: the ability to weigh evidence,

recognize multiple perspectives, understand the nature of scientific and historical reasoning, engage with difference and disagreement, and approach complex problems with empathy as well as rigor.

Learning does not happen in isolation—and neither does change.

The science of learning and development makes clear that young people do not learn in isolation—and neither do the systems designed to support them. Schools, families, communities, and youth-serving organizations are all part of the learning ecosystem. When these systems work together and share a common understanding of how children learn and thrive, the results are far more powerful than any single program or practice. Transforming education requires attention not only to what happens in individual classrooms, but to the broader conditions and relationships that shape learning at every level.

Conclusions

The evidence is compelling and full of promise: All children can learn and thrive if we transform how we educate and support them. But we won't fulfill this promise if we remain focused on compliance and narrow skill-drilling that produces short-term gains but undermines the curiosity, agency, and deeper capacities young people need to thrive over a lifetime—gains that, as decades of longitudinal research including the landmark HighScope studies confirm, matter far more for long-term outcomes. An education system that treats the hours children spend in school as if learning begins and ends there—ignoring the 24/7 reality of how children actually grow, across every environment and relationship in their lives—was never designed to develop every young person fully and too often dismissed or failed to learn from the evidence generated by developmental, community-based, and whole-child approaches that have consistently shown what is possible for all children—when the conditions are right.

We do not pretend to have all the answers about how to design systems that support every child. But twenty-first-century science has given us better answers to problems that have vexed us—knowledge we can use to change lives and reveal the potential of our young people.

The research discussed in this paper shows that all children have talents, that all children can succeed in intentional, well-designed, developmental contexts, and that the methods we currently use to develop, measure, and categorize ability are inadequate for, and in many cases undermining of, our goals. If we hope to educate and empower all children, no matter their background, we must recognize that there may be as many pathways to success as there are individuals.

We still have educational systems that marginalize and exclude far too many children, in particular the growing number of young people who live in underserved communities and who suffer serious stresses. Their needs are not being met, and their talents are not being nurtured.

If education is to be equitable for all, then it is necessary to transform our nation's education systems—to ensure the transformation is deeply informed by the science of learning and

development and designed for equity, which includes creating learning environments that affirm each person's dignity and humanity, and create a foundation for belonging and motivation. Equity begins with recognizing that all learners are whole, capable, and worthy of opportunity.

Equity in this sense is not only about opening doors for individual children. It is about designing systems in which all young people—and the communities they belong to—can thrive together. Thriving, when we create the conditions for it, is collective. This is why equity-centered practice is not an add-on to good teaching—it is the foundation of it.

That redesign is not only about building better conditions alongside what already exists. It requires actively replacing practices that sort, track, exclude, and label children—practices rooted in the false assumption that talent is fixed, scarce, and unevenly distributed. The science is unambiguous: those practices do not reflect how children actually learn and develop. Dismantling them is not a sacrifice of rigor or high expectations. It is what rigor and high expectations actually require.

Educators and system leaders do not have to navigate this work without guidance. The Design Principles for Schools playbook (Learning Policy Institute & Turnaround for Children, 2021) and the planning tool for developing a system for thriving and learning (Fullan, Osher, Junk, & Malloy, 2022) provide concrete, equity-centered frameworks for assessing where a school or system stands and for building toward change. Research on educator preparation shows that teachers who learn to understand and apply the science of learning and development are better equipped to create the conditions in which all children thrive (Darling-Hammond, Schachner, Wojcikiewicz, & Flook, 2024). The 2023 Review of Research in Education includes articles that show how these principles come to life across disciplines—from mathematics and literacy to civics and the arts.

The late educational psychologist Benjamin Bloom was moved by this observation: "What any person in the world can learn," he wrote, "almost all persons can learn if provided with appropriate prior and current conditions of learning." We understand that, given our current reality, this may seem overly optimistic, but the science of learning and development tells us that Bloom is right.

Now that we know better, it's up to us to do better, for all our children.

About This Working Paper

This paper updates a body of work I have been part of building since 2016. That work began with a synthesis of the science of learning and development that I led with Pamela Cantor, Juliette Berg, Lily Steyer, and Todd Rose, research for which I led the literature review and was lead author. It continued through three peer-reviewed papers published in *Applied Developmental Science*, on which I was a co-author, and through the scientific commentaries those papers generated. Together, our collective scholarship formed the foundation for the 2020 SoLD Alliance translation — *How the Science of Learning and Development Can Transform Education* — which I co-authored with the other Alliance

principals: Pamela Cantor, Linda Darling-Hammond, Bethany Little, Scott Palmer, Karen Pittman, and Todd Rose. In 2021, Pamela Cantor and I co-edited and co-authored *The Science of Learning and Development: Enhancing the Lives of All Young People* (Routledge), which brought together those papers, the commentaries, and new scholarship. I have since served as co-lead editor of Volumes 47 and 49 of the *Review of Research in Education*, both centered on the science of learning and development and equity-centered thriving.

Much of the language in this working paper draws directly on the 2020 SoLD Alliance translation, which was itself built on the 2017 synthesis I led. I have preserved that language where it remains accurate, to maintain continuity. The 2020 text represents collaborative work; any departures from it, as well as all new framing and additions, are my own.

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