




The Brain Basis for Integrated Social, Emotional, and Academic Development

How emotions and social
relationships drive learning

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THE ASPEN INSTITUTE
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Introduction

Throughout life, and to an extraordinary degree in young people, the brain develops differently based on opportunities to engage actively and safely with rich and meaningful environments, social relationships, and ideas.¹⁻³ The brain's plasticity, the very adaptability that allows us to adjust to the demands of our environments, therefore presents a critical opportunity and responsibility for education.

Brain science usually does not translate directly into educational policy or practice. But educational policies and practices that are consistent with how the brain develops are more likely to promote learning and development than those that undermine or are inconsistent with brain science.⁴ In addition, an appreciation of how brain development varies across individuals and accommodates environmental demands can give educators insights into the types of supports and interventions that might prove most helpful for different children.⁵⁻⁸

This brief explains the science behind how the brain develops, how that development relates to learning, and the settings and contexts that are conducive to learning and development. It explains how brain development requires social relationships, emotional experiences, and cognitive opportunities. And, it draws from this evidence to suggest basic principles for educational policymakers and practitioners.


Brain development supports learning, and vice versa.

Brain development after birth does not just involve the brain getting bigger or stronger or increasing its number of connections.⁹ Instead, brain development mainly involves the generation, pruning, and reorganization

of neural connections to form brain networks that reflect a person's experiences and help him or her adapt to the world in which they live.^{10,11} As a person engages with situations, problems, ideas, and social relationships, these experiences influence patterns of brain structure and function that undergird a person's changing skills and inclinations over time.

The developmental sculpting of the brain's networks through learning is akin to the process of growing a botanical garden. When given adequate opportunity, plants naturally grow through various developmentally appropriate phases, such as seed germination and cycles of budding and flowering. However, the particular characteristics of a garden reflect the age and types of the plants and a combination of geography, climate, soil quality, care, cultural context (such as preferences for rock gardens versus wildflowers), and the gardener's own choices. The garden is also affected by how it is laid out and used (for example, for picnicking under shade trees, growing vegetables, strolling along paths, or playing active sports). In this way, the local conditions, the gardener's skills and taste, the patterns of use, and time all shape the garden and affect its future growth and health.

Just as a garden grows differently in different climates and with different plants, styles of gardening, and use, a person's brain develops differently depending on age, predispositions, priorities, experiences, and environment. When given adequate opportunity, support, and encouragement, children naturally think, feel emotions, and engage with their social and physical worlds. And these patterns of thoughts, feelings, and engagement organize brain development over time and in age-specific ways, influencing growth, intelligence, and health into the future.



Genes and Epigenetics: An emotionally safe, cognitively stimulating environment contributes to brain development.

In 1990, a major multinational scientific project was launched to document the full genetic makeup of humans. The Human Genome Project¹² resulted in a startling discovery: humans have far *fewer* genes than had been predicted,¹³ and fewer than many simpler organisms, including many plants. How could the most intelligent and flexible creatures on the planet have so few uniquely human genes with which to specify abilities? The answer speaks squarely to the purpose of culture, childrearing, and education: our amazing intellectual potential appears to derive partly from the evolutionary loss of genetic information.^{14,15} Our genes appear to underspecify our development, and that information deficit makes possible (and in fact necessary) our unparalleled proclivity for socially mediated learning.¹⁶⁻¹⁸ For our genes to grow a fully functioning human, we must have adequate opportunity to interact with others and to *learn*. This learning extends across the settings a person lives in: family, community, and school.

While the components of the genetic code could be likened to a gardener's seeds and instruction manual, the epigenetic forces—the environmental forces from “above the genome”—provide the supports and triggers that open and close various pages of the manual, and even reorder, copy, and delete pages, telling the gardener whether, when, where, and how to plant various seeds given dynamic environmental conditions, and how to care for, arrange, prune, and fertilize plants at different stages, in accordance with the

changing weather conditions and the desired uses and appearance of the garden.

Epigenetic forces are like the climate, the weather, and the gardener's actions. They are aspects of the person's social, emotional, cognitive, physical, and physiological contexts—the engaging and rigorous intellectual opportunities, warm and rich social relationships, and healthy physical and emotional environments in which a person lives. Together, these forces trigger and organize brain development and, therefore, a person's readiness and capacities to learn. Though healthy human environments can vary greatly in their specific characteristics and cultural features, when a person's world is seriously impoverished in any of these dimensions, brain development and the learning that depends on it are compromised.^{3,19-21} When a person's world is enriched in these dimensions, brain development is facilitated and learning is enabled.²²⁻²⁵

Except in the rare case of severe, life-threatening genetic disorders, all children have the genes essential for brain development and the propensity to learn. However, genes are not sufficient to build a person, and the genome itself is dynamic, changing in response to environmental cues.²⁶ Continual, age-appropriate, and individualized contextual support provides the epigenetic forces that turn genes on and off, copy and arrange them, so that growth, development, thinking, and learning can occur.²⁷⁻²⁹ Overall, though differences in individuals' intelligence are somewhat heritable in optimal learning environments,³⁰ in sub-optimal environments, measures of environmental quality and learning opportunities overwhelmingly swamp the predictive power of genes.³¹ Following

The quality of a person's relationships and social interactions shapes their development and health, both of the body and of the brain.

the garden analogy, individuals may inherit “seeds” for various kinds of plants, but it is the gardening and environmental conditions that determine which seeds will grow, thrive, and thereby reveal their potential. Importantly, across the lifespan, targeted interventions and supports of the sorts that can be provided by schools and community organizations have been shown to improve neural and cognitive functioning and health, with long-term benefits for individuals.^{21,23,32-35}

The brain development that supports learning depends on social experience.

Think of a hysterical baby up past bedtime, whose distraught parent lifts and hugs her, shushes, lays the little one's head where she can hear the parent's heartbeat, and sings her to sleep. In the minutes that follow, both the baby's and the parent's blood pressure lower, stress hormones normalize, and hormones involved in bonding and social affiliation increase.³⁶ Over the course of these minutes, both the parent and the baby undergo physiological changes that influence not only immune functioning and digestion, but also brain structure, especially in regions associated with learning and memory, and in the adult, with executive functioning, which supports self-regulation and goal-directed behavior.³⁷ Exposure to these socially triggered hormones opens a window of

plasticity in the parent's brain development,³⁸ and signals the infant's brain to grow.³⁹⁻⁴¹

As the above example demonstrates, individuals co-regulate each other's physiology,⁴²⁻⁴⁵ which means that the quality of a person's relationships and social interactions shapes their development and health, both of the body and of the brain.^{37,46-49} For example, infants' prenatal brain development is impacted by maternal stress, which is in turn related to toddler behavior, and child temperament and learning.⁵⁰⁻⁵²

The brains of children and adolescents who experience persistent adversity respond by strengthening circuits that promote aggressive and anxious tendencies at the expense of circuits for cognition, reasoning, and memory.^{53,54} The hormonal signaling molecules responsible for these shifts in neural development are toxic in large amounts, making individuals more likely to develop health problems, including mental health disorders such as addiction, anxiety, and depression,⁵⁵⁻⁵⁹ and physical health problems, such as heart disease, obesity, and cancer.^{60,61} Connections between social and physical maturation are also seen in less extreme conditions: toddlers with poor attachment to caregivers undergo puberty earlier,⁴⁶ as do pre-teen girls whose co-habiting parents are socially aggressive to each other (for example, refusing to talk, threatening to leave).⁶² Stress shortens the window of increased neural plasticity and growth in

adolescence,⁶³ and predicts earlier sexual maturity and worse psychosocial outcomes,⁶⁴ with implications for risky decisions that influence educational outcomes.^{65,66}

As these examples illustrate, the brain functioning that supports learning depends on social experience. The way individuals experience relationships in the home, community, school, and workplace influences their biological development, and hence how they live and think.⁶⁷⁻⁶⁹ Even in adults, close relationships are associated with hormone co-regulation, with implications for cognition, sleep quality, and health.^{70,71} Though the brain is malleable and changed by experience across the lifespan, the most important periods are those in which the brain is most actively changing: the prenatal period through childhood, adolescence, the transition to parenthood, and old age.

Sensitive periods in brain development align with opportunities for learning and needed supports.

The development of the brain and the development of thinking run in parallel; each enables the other. Examining brain development at different stages provides insights into developmentally appropriate learning at each stage and the necessary supportive conditions.

INFANCY: Newborn's brains are highly immature and malleable. They require extensive human interaction to develop. Infants come into the world with a set of neural reflexes that serve as primitive entry-points for regulating themselves in their environment (such as

breathing, eating, and maintaining a steady body temperature) and for interacting with physical objects and other people (for example, through looking and eye contact, listening, grasping, mirroring, vocalizing, and cuddling). In engaging with their caregivers, infants notice patterns of actions, language use, and emotional expression that tune their brain development to the features of their specific environment.

Given their stage of brain development, infants thrive with stable routines, including living routines like feeding, bathing, and sleeping, and cultural routines like simple songs and interactive games. Infants need stable relationships with emotionally healthy, attentive caregivers; adequate nutrition and physical care; and plentiful exposure to language.

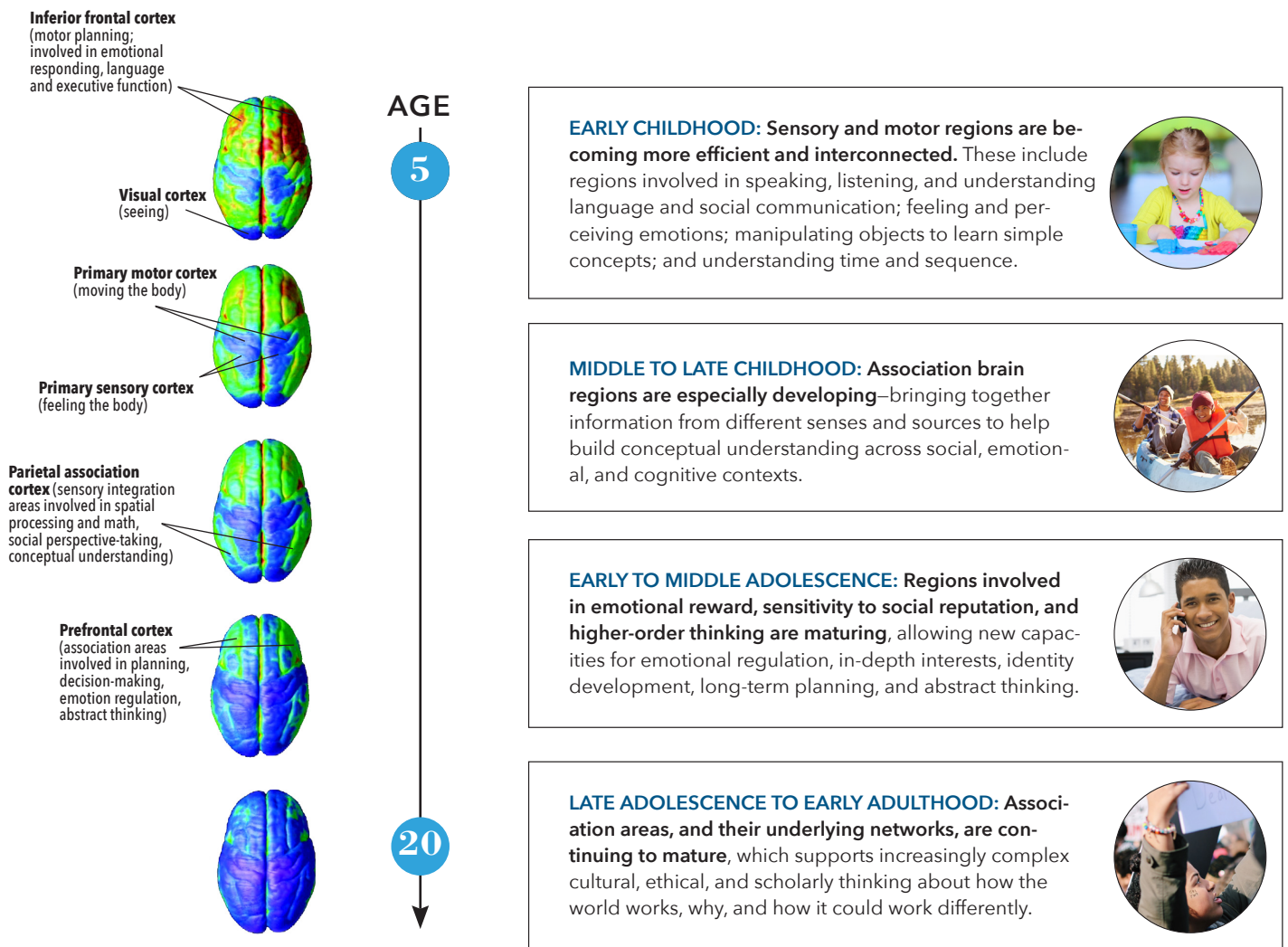
Healthy early care environments feature small ratios of children to adults so that interpersonal interactions are maximized. These interactions offer physical comfort and affectionate holding and hugging to support attachment and a sense of safety, as well as regular communication and responsive, back-and-forth interactions to support infants' development of language and sense-making in the relationships and settings they encounter. In addition to warm, sensitive relationships, these settings also offer regular feeding and good nutrition, sleep, and physical activities, such as sitting, rolling, crawling, and walking with adult oversight.⁷²⁻⁷⁴

EARLY CHILDHOOD: In early childhood, the brain regions that control sensory, motor, language, spatial, and visual functions are maturing.⁷⁵⁻⁷⁷ This brain development coincides with children learning to coordinate their reflexes to form goal-directed actions, such as toddlers coordinating their gesturing and

(Continued on page 6)

FIGURE 1

The Stages of Brain Development and Associated Learning Opportunities



Views of the brain across childhood and adolescence illustrate how different regions develop with varying intensity at different stages. While the sequence of spurts in brain development is relatively universal, there is individual variability in how and when brain regions develop that reflects interactions between

individuals’ propensities and their social, emotional, cultural, cognitive, and physical contexts.

Considering neural developmental sequences together with individuals’ propensities and contexts can therefore provide insight into the developmentally appropriate

activities that young people may engage in, learn from, and enjoy at different stages.

For more on developmentally appropriate learning activities for each stage, see pages 11, 14-16.

NOTE: These brain images illustrate one aspect of how different systems in the brain are developing and maturing from ages 5 through 20 and beyond. As the brain regions change from red to green to blue, the outer cortical layers of the brain are thinning, which in this age range can reflect more consolidated and efficient processing. Think of these images as providing a sense of the relative sequence of maturation of different systems.



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vocalizing to communicate with caregivers, or coordinating their posture, movement, and attention to learn to run, ride a wheeled toy, or read a book with an older person. In order to attain physical milestones, like walking and toileting, and social milestones, like talking and sharing joint attention, young children need predictably calm interactions with responsive and loving caregivers,⁷⁸ and safe opportunities to explore and to share what they notice.

Young children are interested in learning with others about the world—real and imaginary. With conversations and other interactions, imitation, exploration, and self-paced practice, children build simple understandings of sights, sounds, and object properties, as well as of social rituals, language, emotions, and stories.⁷⁹ Through active play and participation in daily activities, they notice patterns of cause and effect, gain agency and a sense of self, and begin to figure out how the world works.⁸⁰ They learn to act alone and with others' help to satisfy their curiosities and achieve their goals.^{81,82}


Much of young children's learning happens through play.^{83,84} Productive early childhood education settings offer rich environments with materials to manipulate—for example, a sand table, water table, blocks, playhouse area, art supplies, musical toys—and regular opportunities to investigate, move, and play

with these materials. Adults in these settings encourage children to play and work together (for example, learning group games or setting up and cleaning up at snack time), as well as to pursue their individual interests.

Productive early childhood education settings provide regular routines—such as circle time, snack time, storybook time, inside and outside play time—that provide a balance of activities and learning opportunities. Songs, stories, and conversations in these settings model and support the development of language; music, dance, and games develop movement and a sense of timing and sequence; drawing, painting, playing, and building with manipulatives develop small motor and hand-eye coordination. All of these activities, along with affirmative and supportive interactions, build the brain's architecture in important ways and help students become ready for more symbolic learning that they can link to these concrete experiences.^{83,85}

MIDDLE-LATE CHILDHOOD: The physical, cognitive, and social achievements of early childhood form the foundation for concepts and skills that emerge when children begin to more formally represent their knowledge of the physical, cognitive, social, and emotional world and self. As children become able to think about what they and others are coming to understand,

Productive early childhood settings provide routines and activities, along with affirmative and supportive interactions, that build the brain's architecture in important ways.



know, feel, and do, the association and planning areas of the brain involved in the integration of information gathered from different senses and sources are maturing. Children's learning involves gradually internalizing and reproducing the patterns, procedures, and beliefs they are exposed to at school, at home, and in the community. This exposure happens through social relationships, emotional experiences, and stories; opportunities for mathematical, spatial, and scientific reasoning; and opportunities to formalize ideas through spoken and written language and the arts.

Structured opportunities to teach and learn from others; to explore, discover, and invent; and to test out the predictive power of their reasoning and calculations, help children construct a sense of scholarly and personal agency. Developing capacities for managing goals, strategies, peer relationships, and feelings are supported by formal social activities like participating in sports teams and music ensembles, and also by informal opportunities for self-direction alone and in social settings, such as recess, free time, and helping out with household chores.^{18,86-88}


Supportive learning environments in middle childhood offer opportunities to engage in inquiries and projects that allow children to set goals, seek answers, evaluate evidence, and draw conclusions; continue to engage in concrete experiences of the world on which they can begin to build more abstract thinking; support productive collaboration with other children in undertaking these and other efforts; teach social and emotional skills such as awareness of and productive ways of articulating and managing feelings, while developing empathy and positive interpersonal relationships; and communicate ideas in multiple artistic, linguistic, and mathematical formats.^{89,90}

EARLY-MIDDLE ADOLESCENCE:

Adolescence is the most dramatic period of brain development after infancy. It is a fundamental period of environmentally (epigenetically) triggered social, emotional, and cognitive growth and plasticity,⁹¹⁻⁹⁴ as well as of vulnerability to mental illnesses such as depression and anxiety.⁹⁵ In the brain, maturation of the amygdala and reward-related structures leads to heightened sensitivity to social cues, such as eye gaze and presence of peers, as well as to social hierarchy, reputation, and physical appearance.⁹⁶ The frontal lobes, involved in planning, decision-making, executive functioning, and higher order thinking, begin a protracted period of intense development (lasting into the mid-twenties) that increases the strength of connections to the amygdala and other neural regions involved in emotional reactivity, social sensitivity and reward. This brain development is associated with risk taking and emotion swings,⁹⁷ but also enables new and initially fragile capacities for emotional regulation, long-term planning, and abstract thinking.⁹⁸

Puberty-related hormonal changes launch a period of neural plasticity that also makes the brain more vulnerable to the effects of stress, social rejection, and sleep deprivation.⁹⁹ These pubertal hormone surges influence brain and bodily maturation, friendships, and romantic attraction,¹⁰⁰ and shift sleep patterns to later and longer.¹⁰¹

Adolescents' optimal development is enabled by deeply exploring and expanding personal interests and technical skills through high-quality coursework, arts, sports, and other activities. Effective activities are designed to help adolescents build constructive, prosocial connections through community involvement, perspective-taking, and meaning-



making. Adolescents' efficacy, agency, and sense of purpose thrive with safe, supported opportunities to explore possible social identities, tastes, interests, beliefs, and values; and to invest in tight relationships with family, peers, and trustworthy adults like teachers, mentors, spiritual leaders, and coaches. Adequate physical activity, social connection, nutrition, and sleep are particularly important in adolescence, as these buffer the effects of stress on the brain and improve well-being, emotion regulation, cognition, and decision-making.

Supportive educational settings for adolescents ensure that they continue to have strong relationships with adults who know them well—often through school advisory systems or teaching teams that can personalize instruction and supports for students in and out of school. Such settings engage students in investigations that allow them to develop critical thinking and problem-solving skills, to debate ideas and reflect on what they are learning, to attempt ambitious projects that interest them, and to receive feedback they can act on to improve their work. These opportunities help them develop a sense of agency, curiosity, habits for reflecting on their own thinking, and a growth mindset and self-regulation to support their ongoing learning.^{89,102}

LATE ADOLESCENCE-EARLY

ADULTHOOD: While in early adolescence the number of neural connections increases, the brain prunes the connections that are not being used during late adolescence,¹⁰³ increasing the brain's efficiency. Which connections remain is determined by a person's thought patterns and engagement with their environment, including by education-related opportunities and social relationships.

Increases in neural “cross-talk” between regions further apart in the brain, especially those involved in higher-level cognition and cultural values, emotions, and beliefs,¹⁰⁴ occur as short-distance connectivity decreases.¹⁰⁵ Tighter communication across, as opposed to within, brain regions during this developmental period¹⁰⁶ supports late adolescents' blossoming abilities to reason, infer, and reflect, through making connections and meaning of their skills, knowledge, and experiences. Opportunities to engage deeply with scholarly ideas, to apply their emerging skills to real-world problems, and to build strong, appropriate peer and adult relationships are crucial for identity development and for making decisions about committed relationships, lifestyle, and careers.

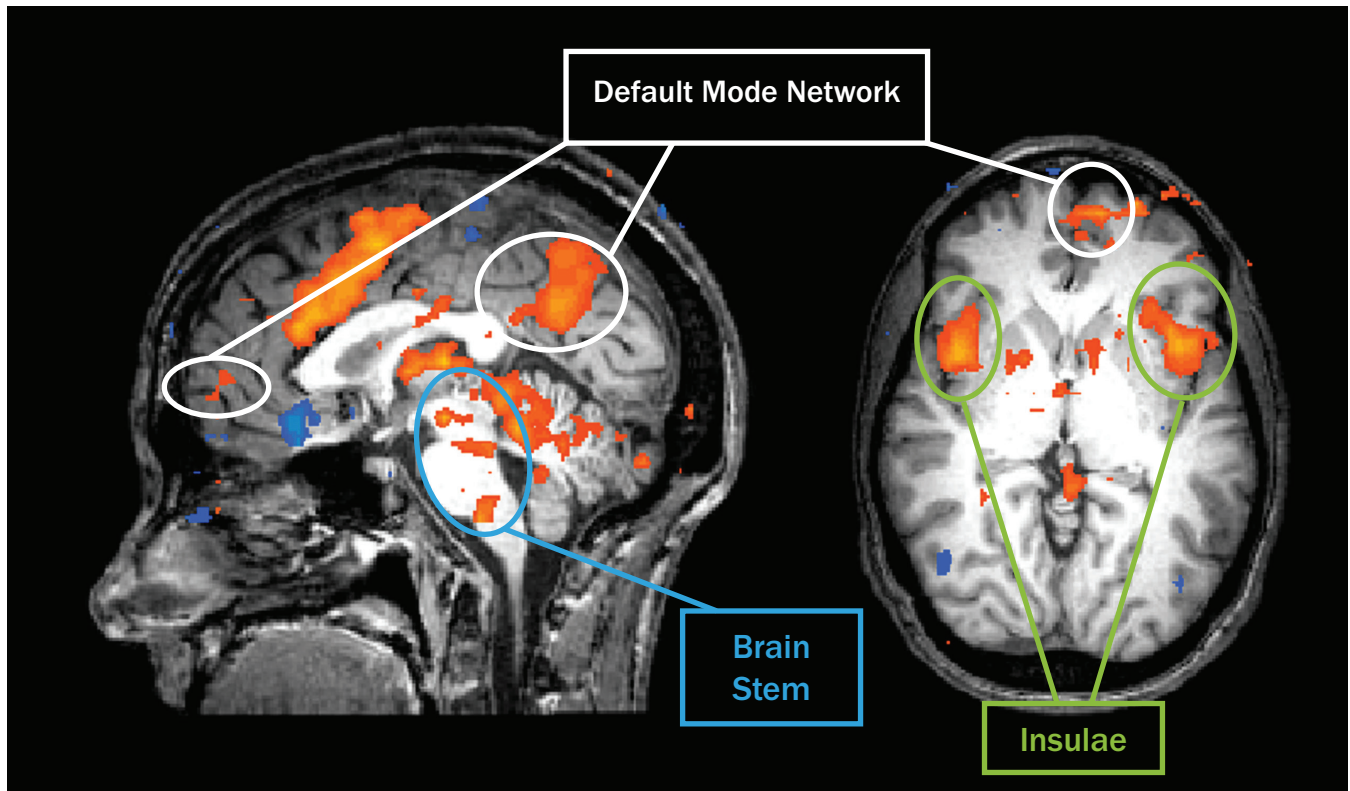
Productive educational settings in late adolescence and early adulthood continue to provide opportunities for young people to be well known by adults with whom they have strong relationships—advisors, mentors, and teachers—and to examine ideas from many perspectives, using symbolic thinking, logic, and metaphor, as well as other tools, to deeply explore meaning. Students should have opportunities to investigate and apply their learning in real-world contexts through projects, internships, externships, and exhibitions, with constructive feedback that allows them to develop ever more disciplined thinking and to tackle ever more advanced problems. They should also have many opportunities to follow their interests and passions in choosing topics and approaches, reflecting on their own strategies so they can guide their own learning over time. And they should be able to engage in personally enjoyable forms of physical activity that they can undertake on their own as well as in groups, and continue throughout life, beyond the education environment.¹⁰⁷

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FIGURE 2

How We Feel

This graphic shows, from a neural perspective, how emotions are crucial to thinking and meaning-making.



The orange in these images depicts regions in the brain that were activated when individuals experienced strong emotions as they watched stories meant to inspire admiration and compassion.

Among the regions of the brain showing heightened neural activity are:

1) **the brain stem**, which is involved in regulating breathing,

heart rate, and other basic survival processes and is essential for consciousness;

2) **the right and left insulae**, which sense the viscera and can be thought of as feeling emotion-related “gut” responses and integrating these feelings with cognitive processes; and

3) **regions of the Default Mode Network** that are involved in processing psychological self,

building coherent narratives, calling up personal memories, and thinking about beliefs and moral values (Immordino-Yang, Christodoulou & Singh, 2012).

Coordinated activity across the insulae, which anchor the Salience Network, and the Default Mode regions (see page 11 for more information), is thought to support reflective, emotionally relevant meaning-making.

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MIDDLE-LATER ADULTHOOD: Though the brain is considered to have reached maturity by middle adulthood, the adult brain undergoes age-related changes that reflect environmental, social, and educational factors.^{2,108} New neurons continue to form in the brain during adulthood in response to new experiences,¹⁰⁹⁻¹¹¹ but this growth can be inhibited by stress,^{112,113} chronic sleep disruption,^{114,115} or dietary deficiencies.^{116,117} Physical and mental activity, as well as social relationships, support adults' brain functioning and help buffer against potential age-related cognitive declines.^{118,119} Consistent with the biological evidence that relationships impact brain development and learning, increasing evidence points to the importance of teachers' mental health and social-emotional skills for students' success.^{120,121}

Productive educational opportunities for adults build on what we know about adult learning: they connect to learners' goals and provide them with new experiences that encompass problem-solving in real-life contexts. Adults typically move through four stages in the experiential learning cycle: engaging in concrete experience; observing and reflecting, often in discussion with peers; forming insights and generalizations; and testing implications of new concepts in new situations.¹²² In line with these insights, effective professional development for teachers—that is, learning that changes teaching practices and student learning—engages teachers in active learning related to the content and students they teach; supports collaboration with colleagues, typically in job-embedded contexts; uses models and modeling of effective practice; provides coaching and expert support; and offers opportunities for feedback and reflection.¹²³

Evidence also shows that teachers' own social-emotional skills and wellness can be

enhanced by training in mindfulness—which develops a calm attentiveness and awareness of experiences, often through regulation of breathing and physical stance, as well as through visualization. Studies find that such training reduces teachers' stress and emotional distress, helps them regulate emotions, and develops greater social-emotional competence, self-efficacy and well-being, so that they can provide more effective emotional support for students.¹²⁴⁻¹²⁷

The major networks of the brain provide a view into the essential dimensions of cognitive, emotional, and social processing and their developmental interdependence.

Though work on the brain from two to three decades ago sought to identify specific brain regions' unique contributions to mental processing, many scientists have shifted to a focus on the networks of connectivity between regions that facilitate different activity modes important for thinking and learning.^{128,129} The basic organization of these networks appears to be present at birth and to develop across the first decades of life,^{106,130-134} but it is the way the brain is used, including how a person thinks, feels, and relates to others, that strengthens and tunes these dynamic networks over time.¹³⁵ The growth and balance of these networks depends in part upon a person's environment, opportunities, and relationships, which together influence the "cross talk" of neurons within the same network and the delicate balance of activity among the networks.¹³⁶⁻¹³⁸

There are three major brain networks that together support a broad range of mental capacities. Through their co-regulation

and coordination, each of these networks contributes to social, emotional, and cognitive functioning, allowing a person to operate well in the world and to take advantage of learning opportunities. Extensive research in adults connects the functioning of these networks to intelligence, memory, mental flexibility and creativity, mental health, capacities for emotion regulation and attention, and other essential abilities.¹³⁹⁻¹⁴² In children, adolescents, and across adulthood, the functioning of these networks correlates with the quality of one's environment, resources, and relationships^{2,3,143} and improves with targeted intervention.^{23,34,144-146} To varying degrees, these networks appear to be malleable across the lifespan.¹⁰⁸

THE EXECUTIVE CONTROL NETWORK:

The Executive Control Network facilitates attention, allowing people to hold information in mind, shift strategies or approaches as necessary, and focus on the completion of goal-directed tasks.^{142,147,148} The Executive Control Network is important for ignoring extraneous information and distractions, as well as for regulating emotions, maintaining goals and focus, and controlling impulses.

THE DEFAULT MODE NETWORK: The Default Mode Network is heavily recruited during all sorts of tasks that involve internally directed, interpretive, and reflective thought, for example when remembering past experiences, imagining hypothetical or future scenarios, or deliberating on inferred, abstract, or morally relevant information,¹⁴⁹⁻¹⁵³ or daydreaming.¹⁵⁴ The Default Mode Network is important for conceptual understanding, reading comprehension, creativity, nonlinear and "out-of-the-box" thinking,^{151,155,156} feelings of inspiration, social emotions like admiration and

compassion,¹⁵⁷ identity development,^{158,159} and for "looking in," or thinking about things that aren't in the physical "here and now."^{151,160}

THE SALIENCE NETWORK: The Salience Network weighs emotional relevance and perceived importance and urgency of information to facilitate switching between mindsets supported by the inwardly focused, meaning-oriented Default Mode Network and those supported by the outwardly focused, task-oriented Executive Control Network.^{141,148,161-163} This switching of mental modes reflects subjective, affective evaluation by the Salience Network of external signals from the environment and internal bodily signals, such as from hunger and anxiety.

Educational Implications

Optimal learning environments attend in age-appropriate ways to developing each of the broad capacities supported by the brain's major networks: this includes sustained, flexible attention and productivity on tasks (roughly speaking, the domain of the Executive Control Network); reflection, memory, and meaning-making (roughly speaking, the domain of the Default Mode Network); and emotional relevance (roughly speaking, the domain of the Salience Network).

Optimal educational activities foster engagement and learning by leveraging opportunities to strengthen, balance, and mutually reinforce these capacities in culturally relevant, meaningful, and productive tasks.¹²⁸ Productive tasks foster motivation and accomplishment by coupling interest and relevance with accessibility—representing the right level of difficulty, in the "zone of proximal

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PHYSIOLOGICAL PRECONDITIONS THAT MUST BE MET FOR OPTIMAL BRAIN DEVELOPMENT AND LEARNING

Environments that support the physiological preconditions for brain development enable learning. For individuals to take full advantage of learning opportunities, certain physiological preconditions must be met.

Among these are:

SLEEP/REST:

Both physical and mental health, and the ability to think well, depend on getting an adequate amount of quality sleep.¹⁶⁴⁻¹⁶⁶ Sleep is fundamental for neural plasticity and the consolidation of memories,^{167,168} as well as for removing toxic proteins that build up in the brain over waking hours.¹⁶⁹ When people are sleep deprived, their brain networks are not as coherently organized or regulated.¹⁷⁰⁻¹⁷³ Over time, chronic sleep deprivation leads to impairments in mood, emotion regulation, memory, cognition, creative thinking, and situational awareness.¹⁷⁴ Individuals vary in the amount of sleep they need, but sufficient sleep is required for optimal learning.

NUTRITION AND LOW EXPOSURE TO TOXINS:

Adequate nutrition and absence of toxins are necessary for healthy brain development, especially in children. Deficiencies in nutrients, such as iron,¹⁷⁵ and diets rich in refined sugars and high in saturated fats,¹⁷⁶⁻¹⁷⁸ have been found to compromise brain development, and can lead to impairments in learning, memory, and cognition. Exposure

to environmental toxins as a result of poor water, sanitation, and hygiene conditions,¹⁷⁹ air pollution,¹⁸⁰⁻¹⁸² and even low levels of lead,^{183,184} have negative impacts on brain development that can be permanent. Exposure to drugs and alcohol, especially among adolescents, has negative impacts on brain development.^{185,186}

PHYSICAL ACTIVITY, EXERCISE, GREEN SPACE:

Physical activity impacts the physiological regulation underlying social and emotional well-being, cognition, and memory.^{187,188} The efficiency and organization of neural networks is supported by fitness.^{189,190} Academic achievement and behavior in children as well as physical and psychosocial well-being and cognition across all ages have been found to improve in the short term and the long term as a result of physical exercise.¹⁹¹⁻¹⁹⁵ Though brain development and learning occur with a sedentary lifestyle, abundant research suggests that physical activity is highly beneficial, and that its beneficial effects are strengthened with the availability of green (natural) space.^{196,197}

EMOTIONAL WELL-BEING, SOCIAL RELATIONSHIPS, AND SAFETY/BELONGING:

In part via the release of hormones that signal the brain and trigger epigenetic effects, emotional well-being promotes health, brain

development, and optimal learning, while chronic and excessive stress and loneliness are toxic to brain development.^{78,198-200} Stress from threats to emotional safety and feelings of belonging, such as stereotype threat, influences a person's underlying physiology and neural functioning, robbing a person of working memory resources.²⁰¹ Such identity-related stress impacts cognitive performance in the short term,²⁰² and in the longer term has been linked to premature aging of the brain and body.^{203,204}

The negative effects of stress can be buffered through supportive parenting, relationships, community, and school programs.^{203,205,206} Exposure to green spaces has also been found to reduce biomarkers of stress and to increase health and well-being.²⁰⁷⁻²⁰⁹ Individuals who have experienced trauma, or toxic stress from abuse or neglect, often require extensive supports and targeted interventions strategically integrated throughout their schooling experience.

CULTURAL WELL-BEING:

An extension of emotional well-being, cultural well-being pertains to the broader roles, group affiliations, and identities that

situate a person within a group and provide a sense of shared history, values, lifestyle, and purpose.²¹⁰ However, when individuals from privileged groups stereotype, marginalize, or oppress members of stigmatized groups, this imposes a lifelong burden on those socially identified with the marginalized group. This impacts cognition as well as physiology.^{202,211} The experience of discrimination—which can pose physical harm, unfair treatment, economic deprivation, stereotype threat, and lack of access to housing, green space, quality food, health care, and other basic needs—is a major source of stress undermining cognition and well-being, with implications for health, brain development, and learning.

Furthermore, if one's cultural beliefs and values feel at odds with those of the dominant cultural group, the conflict can cause misalignment between a person's goals and ways of being and the expectations of the setting.²¹² This perceived invalidation or subordination undermines emotional and social well-being and belonging. Interventions and supports in the home, school, or community that specifically target cultural well-being improve educational, socioeconomic, and health outcomes.²¹³⁻²¹⁶

The negative effects of stress can be buffered through supportive parenting, relationships, community and school programs.

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development,²¹⁷ just beyond a learner's current competence—and supports to enable progress. To be willing and able to tackle challenging tasks, students must also learn to perceive themselves as capable of succeeding, which illustrates the connection between cognitive and emotional capacities.⁸⁹ Learning environments that are structured to be consistent with how the brain develops generally include these features:

They place the learner's emotional and social experience at the forefront. Productive learning environments attend to learners' subjective perceptions and help students build scholarly and social identities that incorporate their new skills and knowledge. They help people to feel safe and purposeful, and to believe that their work is important, relevant, and valuable.

Creating an emotionally safe environment requires schools and classrooms where strong, affirming relationships are built among adults and children. Teachers create classroom communities grounded in respect, in which all students are affirmed for their value, with shared norms and responsibilities for all members.²¹⁸ School structures support personalization, often with teaching teams that share students, advisory systems in which a small group of students are supported by a single advisor over multiple years, and looping, in which students stay with the same teacher for more than one year. Teachers actively help students develop positive academic identities by communicating their interest and belief in the competence of students who may otherwise be threatened by stereotyping and stigma, and by supporting their learning with appropriate scaffolding. Students engage in tasks as scientists, mathematicians, writers, social scientists, and artists, taking on these scholarly roles and identities while learning disciplinary concepts, skills, and modes of inquiry.⁸⁹

They support age-appropriate exploration and discovery. Productive learning environments support age-appropriate exploration and discovery, followed by reflection and discussion for deeper understanding. They support learners in monitoring their own learning, so they can flexibly move between these modes of engagement—knowing when and how to dig in, stop and think, gather more information, or seek help—as they pursue meaningful learning goals.

To support exploration and discovery that adds up to learning important concepts and skills, teachers construct small and large tasks in which students are asked, often in small groups, to explore essential questions using scholarly tools and processes—to figure out how something works, why a phenomenon is as it appears, how to find a solution to a problem, or what will happen if something is done in a particular way—and are provided with access to materials, equipment, and manipulatives to pursue the answers.

Teachers skillfully integrate this inquiry with direct instruction and with opportunities for students to share their thinking and problem-solving strategies, so that students can put general principles and conceptual maps of the domain together with experiential information and specific disciplinary skills. Students have opportunities to teach each other, and through learning how to reflect on, evaluate, and revise their work, they increasingly take control of their own learning process.^{89,219}

They support flexible and efficient thinking. Productive learning environments attend to the trade-off between plasticity and efficiency in brain development,^{220,221} strategically offering activities that encourage flexible thinking along with those that encourage mastery of necessary building-block skills and knowledge.

Productive learning environments attend to the trade-off between plasticity and efficiency in brain development, offering activities that encourage both flexible thinking and mastery of necessary building-block skills and knowledge.


In the United States there has been a tug-of-war between teaching students to pursue conceptual understanding so that they comprehend ideas deeply, and ensuring that they memorize math facts, phonetic sounds, historical facts, or other pieces of information so that they can efficiently retrieve them. Often these debates are grounded in the common misconception that “basic” skills have to precede complex thinking and reasoning, which is not consistent with current models of brain network development.

True, it is important to enable students to learn symbol systems that help organize the brain for academic skills. For example, the basic academic skills of phonological decoding and mathematical calculating specialize specific brain circuits through practice over time.^{222,223} However, it is also true that the very processes of reasoning, conversing, exploring, and conjecturing strengthen the coherence and balance of brain networks, fostering greater intelligence to apply to all kinds of learning tasks. Making sense of reading, for example, requires sense-making abilities and wide-ranging knowledge of the world that supports understanding of the text, as well as decoding skills and attention.²²⁴ The most effective educational strategies typically allow students

to develop conceptual understanding of domains as they engage in hands-on learning and higher-order thinking to build a foundation for situating the more specific, basic skills they will eventually make automatic—moving flexibly between exploration, reflection, and practice.⁸⁹

In addition to basic skills and complex mental processes, various specific features of environments can enhance cognitive processing and flexibility, and beneficial character traits such as open-mindedness. For example, multilingual environments can offer cognitive, social, and emotional benefits,^{225,226} as can playing a musical instrument, engaging in the visual and performing arts, and being physically active in ways that require coordination, social communication, and strategy.^{227,228} These activities can enhance the development of the brain, perceptions of patterns, and reasoning ability in mathematics, visual/spatial fields, and verbal expression.²²⁹⁻²³¹

They help students acquire habits of mind and character. Productive learning environments help students acquire habits of mind that facilitate acquisition of age-appropriate knowledge and skills, reasoning, and ethical reflectiveness.^{232,233} These habits of mind become tools for navigating the world as a



learner, bringing curiosity, interest, persistence, and a deep thirst for understanding.²³⁴

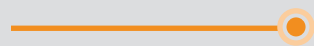
To develop habits of mind such as curiosity, awareness of one's own understanding, and persistence—as well as empathy and ethical reasoning—teachers engage students in extended tasks that incorporate students' interests and choices, and require planning and follow through. These tasks also provide students with opportunities to exhibit and explain their thinking, gain feedback from one another, and revise their work.²³⁵ These processes contribute to deeper learning and help students develop perseverance, resilience, and a growth mindset.²³⁶

Stronger achievement occurs when these tasks are undertaken in a cooperative classroom with a mastery focus where students are recognized for accomplishing their individual and collective learning goals, rather than in a competitive setting that focuses on where students rank or on what grades they have achieved.²³⁷ An emphasis on cooperation can support more ethical and empathetic behavior, as does an emphasis on pursuing work connected to pertinent issues and problems in the world beyond their classroom.^{238,239}

Conclusion

The science on how the brain develops helps explain why young people's social, emotional, and academic development are intertwined.^{240,241} In addition to basic physiological needs like nutrition and sleep, brain development requires social relationships, emotional experiences, and cognitive resources, which ready the brain to take advantage of learning opportunities. To provide purposeful learning opportunities for young people—and strategic opportunities for brain development—requires educators to attend to the development of the whole child in context,²⁴² and to the need for aligned partnerships throughout the community that can support children's and their families' health and well-being.²¹⁵ Educating the whole child, and engaging families and communities in this process, is not just a luxury for those with the opportunity and the means, or a remediation strategy for the underprivileged or underperforming. It is a necessity for all children. Genuinely pursuing an integrated, whole-child approach to education will require substantial innovation in policies and practices, but children's brain development, and the learning that depends on it, are at stake.

All of the citations for this report are available online at
<http://as.pn/braindevtfootnotes>.



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