



Nurturing Nature: How Brain Development is Inherently Social and Emotional, and What This Means for Education

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New advances in neurobiology are revealing that brain development and the learning it enables are directly dependent on social-emotional experience. Growing bodies of research reveal the importance of socially-triggered epigenetic contributions to brain development and brain network configuration, with implications for social-emotional functioning, cognition, motivation and learning. Brain development is also impacted by health-related and physical developmental factors, such as sleep, toxin exposure, and puberty, which in turn influence social-emotional functioning and cognition. An appreciation of the dynamic interdependencies of social-emotional experience, health-related factors, brain development and learning underscores the importance of a “whole child” approach to education reform, and leads to important insights for research on Social-Emotional Learning (SEL). To facilitate these interdisciplinary conversations, here we conceptualize within a developmental framework current evidence on the fundamental and ubiquitous biological constraints and affordances undergirding SEL-related constructs and learning more broadly. Learning indeed depends on how nature is nurtured.

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Abstract

New advances in neurobiology are revealing that brain development and the learning it enables are directly dependent on social-emotional experience. Growing bodies of research reveal the importance of socially-triggered epigenetic contributions to brain development and brain network configuration, with implications for social-emotional functioning, cognition, motivation and learning. Brain development is also impacted by health-related and physical developmental factors, such as sleep, toxin exposure, and puberty, which in turn influence social-emotional functioning and cognition. An appreciation of the dynamic interdependencies of social-emotional experience, health-related factors, brain development and learning underscores the importance of a “whole child” approach to education reform, and leads to important insights for research on Social-Emotional Learning (SEL). To facilitate these interdisciplinary conversations, here we conceptualize within a developmental framework current evidence on the fundamental and ubiquitous biological constraints and affordances undergirding SEL-related constructs and learning more broadly. Learning indeed depends on how nature is nurtured.

Nurturing Nature: How Brain Development is Inherently Social and Emotional, and What This Means for Education

Throughout life, and to an extraordinary degree in young people, the brain develops in relation to opportunities to engage actively and safely with rich and meaningful environments, social relationships and emotions, and socially transmitted ideas and information (Chan et al., 2018; A. Diamond, 2010; Farah, 2017; Immordino-Yang, 2015; Noble et al., 2015). Consistent with foundational work in education and psychology (Bruner, 1990; Montessori, 1914; Vygotsky, 1978), research is revealing that the brain's malleability, the evolutionary plasticity that allows us to adapt to the demands of our environments and to learn, is triggered and organized largely via socially enabled, emotionally driven opportunities for cognitive development. High quality social interaction therefore presents a critical opportunity and responsibility for education.

There is a growing awareness in education research, policy and practice that emotional and social competencies impact learning (Hamilton, Doss, & Steiner, 2019; Jones, Bouffard, & Weissbourd, 2013; Osher et al., 2016; Pekrun & Linnenbrink-Garcia, 2012). An expanding body of educational research focuses on social-emotional learning (SEL), including emotion regulation and awareness, social communication, collaboration skills and the like (Collaborative for Academic, Social, and Emotional Learning, 2015). SEL practices and policies are gaining evidence and traction in mainstream education, and there is coming to be a good deal known about the teachability of SEL, as well as about links between SEL, motivation and academic achievement (Dweck, 2017; Jones & Kahn, 2017; Roeser, Urdan, & Stephens, 2009; Taylor, Oberle, Durlak, & Weissberg, 2017; Wentzel & Miele, 2016).

However, significant questions remain (Jones, Farrington, Jagers, Brackett, & Kahn, 2018). How do social-emotional skills develop, including potential sensitive and high-leverage developmental periods, and what supports are needed at different ages and stages? In an era of unprecedented immigration, diversity, inequality and exposure to trauma, how can we ensure that SEL practices are reliable, culturally responsive, appropriate for individuals' needs, and equitably applied? How are SEL skills, academic emotions, and learning related, and how can SEL skills be most meaningfully integrated into educational experiences? How should social-emotional skills be measured, and for which sets of skills can schools be reasonably held accountable?

In order to help education researchers build toward a new era of SEL research that provides practical answers to these questions, in this article we provide a developmental, biopsychosocial look at *why* and *how* academic learning may be so dependent on culturally situated social relationships and emotional experiences. In particular, we focus on connecting the science of human development with recent neuroscientific insights into the fundamentally social and context-dependent nature of human biology. We integrate a broad range of neurobiological findings into an educationally-relevant narrative elucidating (1) the biological constraints and affordances that derive from the social and emotional contexts in which humans live; and, (2) the ways that developmental processes, including those related to health and physical development, interact with these constraints and affordances.

We take this broad psychosocial approach with the aim of informing the future of SEL, which we see as the educational research and intervention field that focuses specifically on the aspects of behavior and learning that involve interacting with other people and managing one's self, emotions and goals. As science progresses, it is becoming increasingly evident that the

cultural learning and social-emotional experiences that result from everyday human interactions and cognitions play a critical role in brain development and learning across the lifespan. In this sense, human beings are *biologically* cultural (Rogoff, 2003; Tomasello, 2009), and education is a major acculturating force. We believe that an appreciation of the biopsychosocial nature of human development could potentially be useful as SEL researchers work to discern the hidden factors contributing to the SEL constructs they care about, including developmental, contextual, and individual variance. Our main focus is not on specific SEL constructs from the education literature, but instead on how social context and emotional experience, broadly construed, shape the trajectory of human biological development and make learning, including SEL, possible.

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 (Gogtay et al., 2004). 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 (Dennis et al., 2013; Zielinski, Gennatas, Zhou, Seeley, & Raichle, 2010). And after all, this makes good evolutionary and developmental sense. As a person engages with situations, problems, ideas, and social relationships, these experiences influence patterns of brain structure and function that undergird that 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.

Social-Emotional Interactions Are Epigenetic Forces that Make Brain Development Possible, and Contribute to Individual Variability

In 1990, a major multinational scientific project was launched to document the full genetic makeup of humans. The Human Genome Project resulted in a startling discovery: humans have far *fewer* genes than had been predicted (International Human Genome Sequencing Consortium, 2004), 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 (Deacon, 2011). Our genes appear to underspecify our development, and that information deficit makes possible (and in fact necessary) our unparalleled proclivity for socially mediated learning (Rogoff, 2003; Tomasello, 2009). For our genes to grow a fully

functioning human, we must have adequate opportunity to meaningfully 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 on any of these dimensions, brain development and the learning that depends on it are compromised (Butler, Yang, Laube, Kühn, & Immordino-Yang, 2018; Farah, 2017; Harms, Shannon Bowen, Hanson, & Pollak, 2018; Nelson, 2014; Noble et al., 2015). When a person's world is enriched on these dimensions, brain development is facilitated and learning is enabled (M. Diamond, Krech, & Rosenzweig, 1964; Neville et al., 2013; Schore, 2001; Watamura, Donzella, Alwin, & Gunnar, 2003).

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 (Zimmer, 2018). 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 (Carey, 2012; Francis, 2011; Parrington, 2015). In other words, the motivations, sense of agency, social interactions and emotions that form the core of SEL are likely enabling, in the most basic way, the brain development that supports learning.

Overall, though differences in individuals' intelligence are somewhat heritable in optimal learning environments (Plomin & Spinath, 2004), in sub-optimal environments, measures of environmental quality and learning opportunities overwhelmingly swamp the predictive power of genes (Bates, Lewis, & Weiss, 2013). Following 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 school designs, interventions and supports of the sorts broadly related to SEL have been shown to improve neural and cognitive functioning and emotional health, with long-term benefits for individuals (A. Diamond & Lee, 2011; Nelson, 2014; Neville et al., 2013; Oh et al., 2018; Pakulak et al., 2017; Semple, Lee, Dinelia, Ae, & Miller, 2010).

Connecting back to SEL research, the fact that development relies on environmental interactions underscores the potential for significant variability in SEL growth trajectories. While the sequence of spurts in brain development is relatively universal, variability in how and when brain regions develop reflects interactions between individuals' propensities and their social,

emotional, cultural, cognitive, and physical contexts. Considering variability and its sources is, therefore, important for SEL research. Predicting and accommodating this variability would support the design and testing of interventions that leverage or compensate for dynamic person-environment interactions to support healthy development as well as behavior in the moment.

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 child'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 (Gunnar, 1998). 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 (Swain et al., 2017). Exposure to these socially triggered hormones opens a window of plasticity in the parent's brain development (Feldman, 2015), and signals the infant's brain to grow (Curley & Champagne, 2016; Gerhardt, 2014; Sethna et al., 2017).

As the above example demonstrates, individuals co-regulate each other's physiology (Helm, Sbarra, & Ferrer, 2014; Lunkenheimer et al., 2015; Saxbe & Repetti, 2010), 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 (Belsky, Houts, & Fearon, 2010; Fox, Zeanah, & Nelson, 2014; Sapolsky, 2017; Swain et al., 2017). For example, infants' prenatal brain development is impacted by maternal stress, which is in turn related to toddler behavior, and

child temperament and learning (Babenko, Kovalchuk, & Metz, 2015; Kim et al., 2017; Yehuda et al., 2005).

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 (Briggs-Gowan et al., 2015; McLaughlin et al., 2015; Nelson, 2014). This represents a major shift in their SEL trajectory that research and interventions should address. The hormonal signaling molecules responsible for these effects on neural development are also toxic in large amounts, making individuals more likely to develop health problems, including mental health disorders such as addiction, anxiety, and depression (Bick, Fox, Zeanah, & Nelson, 2017; Norman et al., 2012; Shonkoff & Garner, 2012), and physical health problems, such as heart disease, obesity, and cancer (Bucci, Marques, Oh, & Harris, 2016; Dong et al., 2004; Miller & Chen, 2013). Connections between social and physical maturation are also seen in less extreme conditions: toddlers with poor attachment to caregivers undergo puberty earlier (Belsky et al., 2010), as do pre-teen girls whose co-habiting parents are socially aggressive to each other (for example, refusing to talk, threatening to leave; Saxbe & Repetti, 2009). Stress shortens the window of increased neural plasticity and growth in adolescence (Tottenham & Galván, 2016), and predicts earlier sexual maturity and worse psychosocial outcomes (Negri, Saxbe, & Trickett, 2015), with implications for risky decisions that influence educational outcomes (Baams, Dubas, Overbeek, & Van Aken, 2015; Braams, Van Duijvenvoorde, Peper, & Crone, 2015).

As these examples illustrate, the brain functioning that supports learning is related to physical development and depends on social and emotional experience. This brain functioning in turn sets up youths' SEL trajectory, and biases their situational responding. The way individuals

experience relationships in the home, community, school, and workplace influences their biological development, and hence how they live and think (Harris, 2018; Levy, Heissel, Richeson, & Adam, 2016; Royle, Russell, & Wilson, 2014). Even in adults, close relationships are associated with emotions that influence hormone co-regulation, with implications for cognition, sleep quality, and health (Saxbe et al., 2015; Wang & Campos, 2017). Though the brain is malleable and changed by social relationships across the lifespan, the most important periods of SEL are those in which the brain is most actively changing: the prenatal period through childhood, adolescence, the transition to parenthood, and old age. These are also likely to be high-leverage periods for SEL interventions.

The Major Networks of the Brain Provide a View into the Underlying Processing that Supports SEL Capacities

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 (Immordino-Yang, 2016; Sporns, Chialvo, Kaiser, & Hilgetag, 2004). The basic organization of these networks appears to be present at birth and to develop across the first decades of life (Fair et al., 2009; Hoff, Van den Heuvel, Benders, Kersbergen, & De Vries, 2013; Lin et al., 2008; Liu, Flax, Guise, Sukul, & Benasich, 2008; Supekar, Musen, & Menon, 2009), but it is the way the brain is *used*, especially how a person thinks, feels, and relates to others, that strengthens and tunes these dynamic networks over time (Thomason, Hamilton, & Gotlib, 2011). 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 (Greicius, Supekar,

Menon, & Dougherty, 2009; Sporns et al., 2004). Since people are functioning within social and cultural settings, the quality of their interactions, relationships, and associated emotional experiences in these settings will both influence and depend on the functioning of these networks, with implications for SEL-related constructs and for learning more generally.

There are three major brain networks that together support a broad range of mental capacities, many of which, such as emotion regulation, social perspective-taking, intrinsic motivation and others (Immordino-Yang & Sylvan, 2010), can be considered core to SEL. Through their co-regulation and coordination, each of these networks contributes to integrated social, emotional, and cognitive functioning, allowing a person to operate well in the world and to leverage SEL capacities 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 (Buckner, Andrews-Hanna, & Schacter, 2008; Menon & Uddin, 2010; Niendam et al., 2012; van den Heuvel, Stam, Kahn, & Hulshoff Pol, 2009). In children, adolescents, and across adulthood, the functioning of these networks correlates with the quality of one's environment, resources, and relationships (Chan et al., 2018; Noble et al., 2015) and improves with targeted intervention (Anguera et al., 2013; Neville et al., 2013; Pakulak et al., 2017; Rosario Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005; Tang & Posner, 2014). To varying degrees, these networks appear to be malleable across the lifespan (Tian & Ma, 2017), suggesting that SEL interventions have the potential to change the brain, and with it future behavioral tendencies (A. Diamond, 2010).

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 (Beatty, Benedek, Kaufman, & Silvia, 2015; Niendam et al., 2012; Seeley et al., 2007). 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 development of the Executive Control Network is fundamental to SEL capacities, as it is involved in all sorts of SEL skills related to regulation, self-management and self-control (A. Diamond, 2013).

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 (Gilbert & Wilson, 2007; Immordino-Yang, Christodoulou, & Singh, 2012; Raichle et al., 2001; Smallwood, Brown, Baird, & Schooler, 2012; Spreng & Grady, 2010), or daydreaming (Kucyi & Davis, 2014). Overall, the Default Mode Network supports aspects of SEL that involve emotional meaning-making, such as learning from past social and emotional encounters, processing social and self-relevant values and beliefs, and assessing others' emotional motivations, feelings and qualities of character (Immordino-Yang, 2016). For example, the Default Mode Network is activated when reflecting on others' character virtues, but not when appreciating others' more specific physical and cognitive skills (Yang, Pavarini, Schnall, & Immordino-Yang, 2018).

Critically, the Default Mode Network is recruited when task-oriented, goal directed behavior and externally directed attention and perception are attenuated; it does not readily co-

activate with the Executive Control Network. One cannot attend to the outer world and to inner reflections simultaneously. This has important implications for SEL programming and research, in that attention-demanding tasks like listening to the teacher's instructions are relatively neurologically incompatible with mind states reliant on default-mode functioning, like reflecting on a friend's feelings or on the deeper purpose of an activity. SEL skills involving emotionally relevant reflection, future-oriented thinking, and self-relevant meaning-making are suspended when individuals are focused on concrete tasks, or when the environment feels physically or emotionally unsafe and requires vigilance (Immordino-Yang et al., 2012).

Connecting social and emotional capacities with cognitive ones, the Default Mode Network is also important for conceptual understanding, reading comprehension, creativity, nonlinear and "out-of-the-box" thinking (Beatty et al., 2015; Immordino-Yang et al., 2012; Kühn et al., 2014), feelings of inspiration and intrinsic motivation, cognitively complex social emotions like admiration and compassion (Immordino-Yang, McColl, Damasio, & Damasio, 2009), identity development (Molnar-Szakacs & Uddin, 2013), and for "looking in," or thinking about abstract ideas or things that aren't in the physical "here and now" (Immordino-Yang et al., 2012; Tamir, Bricker, Dodell-Feder, & Mitchell, 2015).

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 (Goulden et al., 2014; Menon & Uddin, 2010; Seeley et al., 2007; Uddin, 2015). This switching of mental modes reflects subjective, affective evaluation by the Salience Network of external signals cues from the environment and internal bodily signals,

such as from hunger and anxiety. The most central hub of the Salience Network is located in a brain structure called the insula, which is visceral somatosensory cortex and heavily recruited for “gut feelings”, intuitions, cravings and subjective emotional experience (Immordino-Yang, 2015; Immordino-Yang et al., 2009). In terms of connections to SEL, the functioning of the Salience Network underscores the pivotal role of subjective emotional interpretations and motivations for recruiting neural and associated mental states important for a wide range of mental processes central to learning. The functioning of this network is probably critical, for example, for interpretations of difficulty as reflecting either the “importance” of persisting on a task, or alternately as signaling the “impossibility” of the task, in which case giving up would be adaptive (Oyserman, 2015).

In age-appropriate ways, optimal learning environments integrate SEL into scholarly activities in ways that reflect these three major brain networks. These environments recruit sustained, flexible attention, persistence and productivity on tasks (roughly speaking, the domain of the Executive Control Network); offer support and time for reflection, memory, and meaning-making (roughly speaking, the domain of the Default Mode Network); and leverage emotional relevance (roughly speaking, the domain of the Salience Network).

Health-Related Physiological Factors Impact SEL

As SEL skills rely on the functioning of brain networks, it is important for SEL researchers to be aware of the physiological conditions that support or undermine brain network functioning and thus social-emotional skills and development. Environments that support the physiological preconditions for brain development support social, emotional, cognitive and physical health and enable learning. Among those most relevant to SEL are sleep and rest, nutrition and low exposure to toxins, and physical environments that provide green space and

opportunities for aerobic exercise. Educational researchers should be aware of these factors when studying SEL capacities, developing wrap-around interventions, and assessing intervention outcomes. For SEL capacities to be maximally supported requires a whole child approach that considers environmental and community-level factors (Raymond, 2018), like the availability of parks and playgrounds (Roe et al., 2013). These considerations are especially critical to issues of equity, as children from underprivileged backgrounds are disproportionately exposed to harmful physiological factors, and disproportionately live in environments that do not adequately support beneficial health-related routines and behaviors (Levy et al., 2016; Tessum et al., 2019).

For example, both physical and mental health, and the ability to think well and manage emotions and moods, depend on getting an adequate amount of quality sleep (Ackermann et al., 2012; Van Dongen, Maislin, Mullington, & Dinges, 2003; Walker & Stickgold, 2006). Sleep is fundamental for neural plasticity and the consolidation of memories (Potkin & Bunney, 2012; Rasch & Born, 2013), as well as for removing toxic proteins that build up in the brain over waking hours (Xie et al., 2013). When people are sleep-deprived, their brain networks are not as coherently organized or regulated (De Havas, Parimal, Soon, & Chee, 2012; Yeung, Lee, Cheung, & Chan, 2018; Yoo, Gujar, Hu, Jolesz, & Walker, 2007), resulting in reciprocal declines in cognitive, as well as SEL, capacities. Over time, chronic sleep deprivation leads to impairments in mood, emotion regulation, memory, cognition, creative thinking, and social and situational awareness (Durmer & Dinges, 2005). Individuals vary in the amount of sleep they need, but sufficient sleep is required for emotional wellness, well-regulated social behavior, and optimal learning and motivation.

Adequate nutrition and absence of toxins in the environment are also necessary for healthy brain development and social-emotional functioning, especially in children. Across the

lifespan, quality of diet is related to quality of the gut microbiome, which is related to physical and emotional health and cognitive functioning (Mohajeri, La Fata, Steinert, & Weber, 2018; Sarkar et al., 2018). Deficiencies in nutrients, such as iron (Todorich, Pasquini, Garcia, Paez, & Connor, 2009), and diets rich in refined sugars and high in saturated fats (Francis & Stevenson, 2013; Molteni, Barnard, Ying, Roberts, & Gomez-Pinilla, 2002; Wu, Ying, & Gomez-Pinilla, 2004) have been found to compromise the gut microbiome and brain development, and can lead to impairments in learning, memory, emotion and mood, cognition and motivation. Exposure to environmental toxins as a result of poor water, sanitation, and hygiene conditions (Ngure et al., 2014), air pollution (Fonken et al., 2011; Younan et al., 2018), and even low levels of lead (Bellinger, Stiles, & Needleman, 1992; Koller, Brown, Spurgeon, & Levy, 2004), have negative impacts on brain development that can be permanent. These effects are felt in the SEL domain as increases in anxiety, restlessness and aggression (Ferguson, Cassells, MacAllister, & Evans, 2013; Younan et al., 2018). Exposure to drugs and alcohol, especially among adolescents, has negative impacts on brain development (Camchong, Lim, & Kumra, 2017; Spear, 2018), and increases risk for impaired regulation, and affective and social functioning (Dahl, 2004).

Physical activity also impacts the physiological regulation underlying social and emotional wellbeing, cognition, and memory (Erickson et al., 2011; Hillman, Erickson, & Kramer, 2008). The efficiency and organization of neural networks is supported by fitness (Krafft et al., 2014; Voss et al., 2010). Academic achievement and behavior in children, as well as physical, mental, and psychosocial wellbeing across all ages, have been found to improve in the short term and the long term as a result of physical exercise (Bherer, Erickson, & Liu-Ambrose, 2013; Bunketorp Käll, Malmgren, Olsson, Lindén, & Nilsson, 2015; Koutsandréou, Wegner, Niemann, & Budde, 2016; Lees & Hopkins, 2013; Voss, Nagamatsu, Liu-Ambrose, &

Kramer, 2011). Though brain development and learning occur with a sedentary lifestyle, abundant research suggests that physical activity is highly beneficial, and that its beneficial social-emotional and cognitive effects are strengthened with the availability of green (natural) space (Bowler, Buyung-Ali, Knight, & Pullin, 2010; Hyvönen et al., 2018). Exercise, especially in green space, improves mood, and decreases anxiety and stress (Thompson Coon et al., 2011)—all of which have direct implications for SEL, for example by making it easier to regulate negative emotion.

SEL Research Can Be Informed by Evidence for Sensitive Periods in Social-Emotional Brain Development

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. This information could be especially pertinent as SEL researchers begin focusing increasingly on developmental questions (Jones et al., 2018), since sensitive periods align with opportunities for learning. Sensitive periods could also be relevant for designing developmentally appropriate strategies for integrating SEL supports into early childhood to post-secondary education and assessments. In what follows, we highlight sensitive periods in social brain development and situate them in a broader developmental trajectory.

One major domain in which sensitive periods emerge concerns emotional well-being, most notably in the context of social relationships and individuals' associated sense of safety and 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 (Cacioppo & Patrick, 2008;

Lupien, McEwen, Gunnar, & Heim, 2009; Shonkoff, 2011; Zilkha & Kimchi, 2018). 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 (Beilock, Rydell, & McConnell, 2007). Such identity-related stress impacts cognitive performance in the short term (Steele, 2011), and in the longer term has been linked to premature aging of the brain and body (G. H. Brody, Yu, Chen, Beach, & Miller, 2016; Miller, Yu, Chen, & Brody, 2015). The negative effects of stress can be buffered through supportive parenting, relationships, community and school programs (Asok, Bernard, Roth, Rosen, & Dozier, 2013; G. H. Brody et al., 2016; Flannery, Beauchamp, & Fisher, 2017; Khoury, Sharma, Rush, & Fournier, 2015). Exposure to green spaces has also been found to reduce biomarkers of stress and to increase health and wellbeing (Roe et al., 2013; Thompson et al., 2012; Twohig-Bennett & Jones, 2018). 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 (Harris, 2018).

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 (Gutiérrez & Rogoff, 2003). However, when individuals from privileged groups stereotype, marginalize, or oppress members of stigmatized groups, this imposes a lifelong emotional burden on those socially identified with the underprivileged group that impacts cognition as well as physiology (Levy et al., 2016; Steele, 2011; Yip, 2018). 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 social-emotional well-being, with implications for health, brain development, and learning (Shonkoff & Garner, 2012). 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 (Nasir, 2011). 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—in large part because they support SEL (Gutiérrez, 2008; Kirmayer, Groleau, Guzder, Blake, & Jarvis, 2003; Patton, 2010; Raymond, 2018).

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; Brazelton, Koslowski, & Main, 1974; Johnson, Slaughter, & Carey, 1998). In engaging with their caregivers, infants notice patterns of actions, language use, and emotional expression (Snow, 1977) that tune their brain development to the features of their specific environment (Kuhl, 2010). 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 (Gopnik, Meltzoff, & Kuhl, 2000). Infants need stable relationships with emotionally healthy, attentive caregivers (Tronick, 1989); adequate nutrition

and physical care; and plentiful exposure to language (Romeo et al., 2018; Shonkoff & Garner, 2012).

Given the social-emotional needs of infants, healthy early-care environments feature small ratios of children to adults so that interpersonal interactions are maximized (Bornstein, Hahn, Gist, & Haynes, 2007). 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 regulated turn-taking, 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 (NICHD Early Child Care Research Network, 2002; Peisner-Feinberg et al., 2001; Shonkoff & Garner, 2012). These activities allow babies to develop secure attachments, a sense of safety, and a capacity to explore, all of which promote their later ability to notice others' feelings and behaviors and to care for others, as well as to develop confidence in using their own resources for learning (Gopnik et al., 2000).

Early Childhood

In late infancy and early childhood, the brain regions that control sensory, motor, language, spatial, and visual functions are maturing (B. A. Brody, Kinney, Kloman, & Gilles, 1987; Deoni, Dean, Remer, Dirks, & O'Muircheartaigh, 2015). This brain development coincides with children learning to coordinate their reflexes to form goal-directed actions, such as toddlers coordinating their gesturing and 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. Showing emotions is a key form of communication at this age

(Gopnik et al., 2000; Tronick, 1989). 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 (Shonkoff, 2011), and emotionally and physically safe opportunities to explore and to share what they notice.

Young children are interested in learning with others about the world—real and imaginary. Young children’s social learning is unparalleled in the animal kingdom, and is tied to uniquely human forms of intelligence (Tomasello, 2009). 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 (Grazzani, Ornaghi, Conte, Pepe, & Caprin, 2018; Suprawati, Anggoro, & Bukatko, 2014). 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 (Shtulman & Carey, 2007). They learn to act alone and with others’ help to satisfy their curiosities and achieve their goals (Onishi & Baillargeon, 2005; Spelke, Breinlinger, Macomber, & Jacobson, 1992). Critical to attaining these important goals are the social-emotional skills involved in making friends and figuring out how to engage with others: how to empathize, share, play cooperatively, wait patiently, and take turns, as well as to solve conflicts or problems and manage anger or frustration. Each of these skills contributes developmentally to core aspects of SEL important for schooling, such as motivation, self-determination, self-regulation and self-awareness.

Much of this skill development happens through play (Golinkoff & Hirsh-Pasek, 2016; Hirsh-Pasek, Golinkoff, Berk, & Singer, 2009), during which a wide range of behaviors can be modeled and practiced, including those that comprise SEL. 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 snack time), as well as to pursue their individual interests (Bodrova & Leong, 2007; Lillard, 2005).

Regular routines—such as circle time, snack time, storybook time, inside and outside play time—provide a balance of activities and learning opportunities that allow for both novelty and predictability, so that children can learn to engage with others, take turns, and discuss how to handle different situations—all critical precursors to later childhood social-emotional skills. 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 counting and building with manipulatives develop small-motor and hand-eye coordination, and cognition (Carpenter et al., 2017; Peisner-Feinberg, 2001). All of these activities, in the context of affirmative and supportive interactions, build the brain’s network architecture in important ways and help students become ready for more symbolic learning that they can link to these concrete experiences (Hirsh-Pasek et al., 2009; Wechsler, Melnick, Maier, & Bishop, 2016).

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, 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 cognitive and social-emotional 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.

At this developmental stage, SEL capacities and scholarly capacities are becoming increasingly integrated (Immordino-Yang, 2015). 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 and emotional wellbeing. 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 (Barker & Munakata, 2015; A. Diamond, 2014; Paradise & Rogoff, 2009; Rogoff, 2003).

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; and communicate ideas in multiple artistic, linguistic, and mathematical formats (Anderson, 2002). These environments also 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 (Darling-Hammond, Flook, Cook-Harvey, Barron, & Osher, 2019; Taylor et al., 2017).

Early-Middle Adolescence

Adolescence is a dramatic period of brain development. It is a fundamental period of environmentally (or epigenetically) triggered social, emotional, and cognitive growth and plasticity (Crone & Dahl, 2012; Foulkes & Blakemore, 2018; Mychasiuk & Metz, 2016; Silvers et al., 2012), as well as of vulnerability to mental illnesses such as depression and anxiety (Lichenstein, Verstynen, & Forbes, 2016). 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 (Albert, Chein, & Steinberg, 2013). The frontal lobes, involved in planning, decision-making, executive functioning, and higher order thinking, begin a protracted period of intense development (lasting into the early twenties) that increases the strength of connections to the amygdala and other subcortical neural regions involved in emotional reactivity, social sensitivity and reward. This brain development is associated with risk-taking and emotion swings (Albert et al., 2013; Blakemore, 2018), but also enables new and initially fragile capacities for emotional regulation, long-term planning, and abstract thinking (Dahl, 2004).

Puberty-related hormonal changes launch a period of neural plasticity that also makes the brain more vulnerable to the effects of stress and social rejection, particularly under conditions of sleep deprivation (Meyer, Lee, & Gee, 2018). These pubertal hormone surges influence brain and bodily maturation, friendships, and romantic attraction (Suleiman, Galván, Harden, & Dahl, 2017), and shift sleep patterns to later and longer (Carskadon, 2002). Each of these changes impacts SEL directly or indirectly.

Adolescents' optimal development is enabled by deeply exploring and expanding personal interests and technical skills through high quality coursework, arts, sports, and other

activities (Mehta, 2019). 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 wellbeing, emotion regulation, cognition, and decision-making (Blakemore, 2018).

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 (Eccles & Roeser, 2009; Osher & Kendziora, 2010). 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 (Darling-Hammond et al., 2019; Farrington et al., 2012).

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 (Giedd et al., 1999), 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 (Immordino-Yang & Yang, 2017), occur as short-distance connectivity decreases (Kundu et al., 2018). Tighter communication across, as opposed to within, brain regions during this developmental period (Fair et al., 2009) supports late adolescents’ blossoming abilities to reason, infer, and reflect, through making connections and meaning of their skills, knowledge, and experiences (Fischer & Bidell, 2006). 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 (Zarrett & Eccles, 2006).

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 (Farrington, 2012; Mehta, 2019). 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 (Zarrett & Eccles, 2006).

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 (Chan et al., 2018; Tian & Ma, 2017). New neurons continue to form in the brain during adulthood in response to new experiences (Eriksson et al., 1998; Lledo, Alonso, & Grubb, 2006; Zhao, Deng, & Gage, 2008), but this growth can be inhibited by stress (Mirescu & Gould, 2006; Mirescu, Peters, & Gould, 2004), chronic sleep disruption (Lucassen et al., 2010; Meerlo, Mistlberger, Jacobs, Heller, & McGinty, 2009), or dietary deficiencies (Poulose, Miller, Scott, & Shukitt-Hale, 2017; Stangl & Thuret, 2009). Physical and mental activity, as well as social relationships, support adults' brain functioning and help buffer against potential age-related cognitive declines (Charles & Carstensen, 2009; Kramer & Erickson, 2007). 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 (Jennings & Greenberg, 2009; Meiklejohn et al., 2012).

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 (Kolb, 1984). 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 (Darling-Hammond, Hyler, & Gardner, 2017).

Evidence also shows that teachers' own social-emotional skills, sleep quality and wellness can be enhanced by training in mindfulness—which develops a calm attentiveness and awareness of experiences, often through regulation of breathing, physical stance, and stress, 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, sense of self-efficacy and well-being, and emotional support for students (Benn, Akiva, Arel, & Roeser, 2012; Crain, Schonert-Reichl, & Roeser, 2017; Jennings, Frank, Snowberg, Coccia, & Greenberg, 2013; Roeser et al., 2013).

Carving nature at its joints: Researching developmental processes and contextual affordances in both education and neuroscience

A review of the biopsychosocial context for learning makes clear the need for integrated research perspectives that consider developmental processes in relation to contextual affordances to move the field forward. In the real worlds of families, schools and communities, social, emotional and cognitive capacities are fully psychologically and neurobiologically intertwined. There are no brain networks, for example, that process only social, emotional or cognitive information. In fact, all brain networks appear to contribute to social, emotional and cognitive processing, depending on how they are engaged. And all brain networks show the effects of past social, emotional and cognitive experience on their functioning. Accordingly, answers to the currently most pressing SEL-related questions—questions about development and sensitive/high leverage periods; about connections to academic learning and emotions; about variability; about equity; and about assessment and accountability—will not map well onto our existing theoretical

trifecta without extensive qualifications and circular definitions. Instead, answering these questions will rely on understanding the dynamic *interdependence* of multiple systems and capacities *in context*. For researchers in both education and neuroscience to make headway, we need to design innovative research and pedagogical approaches capable of capturing and capitalizing on these dynamics.

In effect, while “social, emotional and cognitive” processes lend themselves nicely to scientific analysis, in living people they are not different or dissociable things, but qualitatively different dimensions of one thing: the situated, embodied and embrained human mind (Immordino-Yang, 2015). Effective learning environments leverage multiple dimensions of the mind in service of strengthening a person’s enactable skills and inclinations (see Immordino-Yang, Darling-Hammond and Krone, 2018, for extended discussion). They do this by skillfully attending to people’s thinking and meaning-making dynamically in context while taking into account the adaptations, dispositions, skills and knowledge individuals bring based on their lived experiences (Darling-Hammond et al., 2008).

Real students and teachers engage social, emotional and cognitive processes *all at once* (Fischer & Bidell, 2006), based on their subjective interpretation of the situation and goals (Oyserman, 2015). To learn math, for example, involves processing quantities, spatial information and logical relationships, and this processing is neuropsychologically activated and steered by emotions, attention and motivations (Immordino-Yang & Damasio, 2007), feelings of competence, safety and belonging (Nasir, 2011), and the quality of memories formed in previous encounters, as well as what the person sees value in accomplishing (Wentzel & Miele, 2016). There is no such thing as math cognition devoid of an emotional impetus or agnostic to its socio-cultural context. In math, just as in any other kind of learning, social, emotional and cognitive

processing are each importantly contributing, and become integral dimensions of one's abilities and inclinations. Even when a person is working alone, removing any of these contributions from the explanation gives an incomplete view, as individuals think in accordance with cultural orientations, beliefs and values that have been cumulatively shaped by their lifetime of socially framed experiences (Bruner, 1990; Vygotsky, 1978). The pressing questions listed above are difficult and important exactly because they cannot be encapsulated within one of the three domains of capacities. They deal with understanding the range of ways that whole people in the real world think and feel. Answering each will therefore require understanding the critical features of the situation in relation to the teachers' and learners' developmental histories, physiological factors and personal inclinations, and how these interact with the relevant cultural, physical and educational affordances.

Examining recent advances in education highlights promising progress toward an integrated, dynamic approach. For example, Carpenter, Franke, Johnson, Turrou, and Wager (2017) explain how effective math teaching involves strategically engaging with students around their mathematical thinking, a process that inherently engages social relationships, agency and past experiences to build meaning and identity together with mathematical competence. Many others have argued for culturally relevant pedagogy that attends to students' personal experiences of scholarship (e.g., Gutiérrez, 2008; Hantzopoulos, 2016; Love, 2019; Nasir, 2011), and new attention is being paid to the design of engaging learning environments (e.g., Schneider, Krajcik, Lavonen, & Salmela-Aro, expected 2020). The arguments presented in this article and elsewhere (e.g. Immordino-Yang, 2016) may give additional insight into the neurobiological mechanisms and processes undergirding the success of these approaches, and with such insight could come further understanding and innovation. We hope this interdisciplinary work will help educational

researchers explicitly consider how their questions, methods and interventions constrain, capture and support developmental processes and affordances. In parallel, to produce work that is most useful to educators, we hope neuroscientists might consider expanding and documenting the individual variability, cultural histories, and lived experiences of their research participants to the extent possible, in order to construct more ecologically valid tasks and interpretations of findings (Immordino-Yang, 2013; Immordino-Yang & Yang, 2017).

Our argument here in no way negates the usefulness of existing research that focuses separately on social, emotional and cognitive capacities, either from education or from neuroscience. Instead, we echo others' arguments that the devil for application to pedagogy across diverse settings is in appreciating the contextual and individual dynamics. Satisfying and impactful answers to our messiest real-world educational problems, answers that will help learners, educators and policy-makers know what to do, may become more readily apparent if we carve the problem space not into sets of social, emotional and cognitive capacities that can be advanced or deficient, but into patterns of thought, behavior and meaning-making (Ritchhart, Church, & Morrison, 2011) that honor the person's subjective experience in context (Darling-Hammond et al, 2008). Education is meant to enable the mind by guiding, expanding, constraining and refining the developmental process. Views into the situated dynamics of the developmental process ought, then, to prove useful as units of analysis.

In sum, current educational psychology research generally carves the problem of how people learn into social, emotional and cognitive capacities, examined as average effects described relatively independently of developmental and biological contexts. This approach launched a highly productive period of research, mainly because it called attention to the previously neglected social and emotional dimensions of learning. But it is now becoming

apparent that we cannot adequately describe or predict individuals' capacities in any of these three domains without taking great pains to qualify the domains' interdependencies and the context. A new frame might better and more parsimoniously organize and synthesize what we know, furthering progress on the goal of designing contextually relevant future research that improves the quality of educational outcomes by focusing on individuals' experiences.

Toward a Developmental, Biopsychosocial Context for SEL Research

A review of humans' nurturing nature makes clear the fundamental responsibility of educational research and institutions to attend to the development of the whole child (Osher et al., 2016), as well as the need to study children's SEL capacities in broader developmental and biopsychosocial context. Because SEL relies on the same brain networks involved in other aspects of mental and physical functioning, it is situated within a broader set of developing, interdependent, situation-contingent capacities. These capacities reflect, and reciprocally shape, a person's lived experience, with consequences for how people think, make decisions, and learn. Though brain science rarely translates directly into educational policy, practice or research programs (Immordino-Yang & Gotlieb, 2017), we hope that the arguments presented here provide researchers with background knowledge that may help with the interpretation of the existing SEL evidence base, as well as lead to future theoretical models, hypotheses and testable interventions. In particular, a neuroscientific perspective on SEL could lead to a deeper appreciation of how brain development varies across individuals and accommodates environmental demands, and provide education researchers with insights into the types of supports and interventions that might prove most helpful for different children at different times (Haft, Myers, & Hoeft, 2016; Hahn, Nierenberg, & Whitfield-Gabrieli, 2017; Raizada & Kishiyama, 2010). Given the importance of epigenetic effects of relationships both in and out of

school, it also points to the need to support and study community-embedded, multigenerational resources.

Unsurprisingly, when children (and the adults that care for and teach them) are socially and physically well and self-regulated, they think better. Attending to SEL capacities and the contexts that support them, therefore, supports social-emotional and physical wellness, as well as scholarly achievement and cognition. 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. An appreciation of the biopsychosocial and developmental contexts for SEL makes clear that attending to social-emotional experience in educational settings is a societal responsibility and a necessity for all children.

Based on a new evidence-based appreciation of the fundamentally social-emotional nature of human brain development—after all, it is largely socially transmitted, emotionally salient epigenetic triggers that teach the brain how to grow and think—we argue for the need to attend more systematically to the person-centered dynamics of learning in both education and neuroscience research, and to focus explicitly on deciphering the influences of the layered contexts in which a person learns. This is aligned with SEL researchers' work redefining “learning” to transcend pure cognition. And even SEL, it is now clear, is situated in the broader context of multiple, interdependent dynamic systems, some of which may transcend currently available constructs.

Genuinely engaging an integrated, whole-child approach to education will require substantial innovation in policies and practices infused across the processes and institutional structures of education and teacher training. SEL research and intervention, especially when

strategically integrated into academic learning opportunities and embedded in community contexts, will be key to this endeavor. Doing this well will be difficult, but children's brain development, and the learning that depends on it, are at stake.

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