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ABSTRACT

The rapidly moving frontiers of neuroscience, molecular biology, and epigenetics—combined with extensive research in the behavioral and social sciences—are dramatically expanding our understanding of how children develop, how that process can be disrupted, how to get it back on track when it does get derailed, and how to keep it from going off track in the first place. The challenge for educators, other practitioners, policymakers, and change agents across sectors lies in our collective ability to transform cutting-edge knowledge into design principles and concepts that can inform an actionable game plan. The first step in addressing this challenge is the need to identify the most important factors that affect individual variation in learning and behavior—a task that demands recognition of the inextricable interaction between environmental influences and genetic predispositions. Building on this foundational understanding, progress toward substantially better life outcomes for all children will require attention to three objectives: (1) making complex science understandable and accessible for strategically targeted audiences; (2) making credible knowledge usable for educators, other practitioners, parents, policymakers, and civic leaders; and (3) leveraging continuing advances in science to build an R&D platform that drives innovation across multiple sectors within a dynamic ecosystem. The opportunities to leverage scientific insights to catalyze fresh thinking and test new ideas in practice and in policy are plentiful and growing, while the barriers to progress remain formidable. The time to seize the opportunities and overcome the barriers is now.

What can discoveries in neuroscience, molecular biology, and epigenetics—combined with advances in the behavioral and social sciences—teach educators, policymakers, parents, and the general public about how to strengthen the building blocks of learning and development? What is it about the stresses associated with poverty, violence, racism, and maltreatment in childhood that can get "under the skin" and have lifelong effects on academic achievement, economic productivity, and responsible citizenship? How can science be harnessed to catalyze new strategies that will transform the lives of children facing adversity while generating substantial benefits for all children and society as a whole?

These are the questions that motivate the two articles in this issue authored by Osher, Cantor, Berg, Steyer, Rose, and their colleagues from the Science of Learning and Development Project (SoLD) (Cantor, Osher, Berg, Steyer, & Rose, in press; Osher, Cantor, Berg, Steyer, & Rose, in press). And these are the questions that must be answered by individuals, institutions, systems, and policies that are responsible for the healthy development and education of all children, beginning in the prenatal period and extending into the adult years. The rich content and broad scope of these articles illustrate the wealth of rapidly advancing knowledge that is available for translation and application. The collective expertise and energy driving the authors and their colleagues underscores the current opportunities for science-based innovation in education and the implementation challenges facing those who are leading this effort.

Kurt Lewin, regarded by many as the founder of social psychology, identified the heart of both the challenges and the opportunities of leveraging science to drive social change when he was reported to have said that if you want to truly understand something try to change it. The rapidly moving frontiers of the biological, behavioral, and social sciences are dramatically expanding our capacity to take on Lewin's challenge. These discrete yet converging domains of knowledge are advancing a deeper understanding of how children develop, how that process can be disrupted, how to get it back on track when it does get derailed, and how to keep it from going off track in the first place. The "devil in the details" lies in our ability to transform the rich and wide-ranging scientific content of these two articles into core concepts that can inform an actionable game plan.

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The first step in addressing this challenge is the need to identify and explain the most important influences on learning and development. As described in the two articles by Osher, Cantor, et al. [in press], neither environments nor genes alone tell us what we need to know about the determinants of human variation. Genetic factors do not predict outcomes without information about environmental influence, and vice versa. Many children who experience significant hardship do not have problems in learning, and many children who face little adversity have difficulties in school. Neither the discovery of a cluster of "high risk" genes nor the application of rating scales of adverse childhood experiences alone provides sufficient information to address the remarkable variability in human response to stress. Thus, the frontiers of twenty-first century biology are moving us beyond the concepts of vulnerability or resilience as traits and focusing instead on understanding differential sensitivity to context as a framework for promoting positive developmental trajectories for all children, regardless of their life circumstances (Boyce, 2015).

Building on this foundational understanding, progress toward substantially better outcomes for children will require significant attention to three objectives: (a) making complex science understandable and accessible for strategically targeted audiences; (b) making credible, scientific knowledge usable for practitioners, parents, policymakers, and civic leaders; and (c) leveraging continuing advances in science to build an R&D platform that drives innovation across multiple sectors.

Making science accessible

The essence of effective translation across disciplines and sectors is understanding that science does not speak for itself. The implications and practical application of scientific knowledge for learning must be translated into accessible language for nonscientists that is accurate, relevant, and credible, and that overcomes existing preconceptions and other barriers to understanding. This translation process is, in itself, an empirical endeavor that requires not only discovering what experts know about a given topic, but also what the public believes and what cultural values, prior knowledge, and deeply held beliefs people use to make sense of new information. Only by understanding and bridging the gaps between "expert knowledge" and the "dominant frames" of the target audience can new information have its desired effect on behaviors and decision-making (Kendall-Taylor & Levitt, 2017; Shonkoff & Bales, 2011).

Translated science has greater salience and more sustainable credibility when it is focused largely on well-established principles (not on isolated studies) and when it describes causal mechanisms (rather than simply report statistical associations). The "active ingredient" of this approach is a coherent narrative that helps key audiences understand the process of development, both behaviorally and in the brain, in a way that leads to fresh thinking about how to improve the life prospects of all children.

The SoLD initiative has achieved a promising starting point in this process by aggregating, synthesizing, and critically analyzing the extensive body of knowledge contained in the two papers included in this issue (Cantor et al., in press; Osher et al., in press). The following five themes (drawn from selected sections) capture a significant proportion of that content and provide a useful framework for an initial communications strategy:

- Understanding the importance of relationships and personal context is essential for guiding effective practice, formulating successful policies, and catalyzing productive innovation. (See section on *Relationships as Drivers of Human Development: Positive Supportive Contexts*) (Osher, et al., in press).
- Understanding the concept of toxic stress (and differentiating it from positive and tolerable stress) is essential for protecting children from the consequences of unbuffered adversity and for building their capacity to cope successfully with hardships and threats to well-being. (See section on *The Science of Stress*) (Cantor et al., in press).
- Understanding the meaning of increased sensitivity to context (i.e., a characteristic of some children that manifests as greater susceptibility to stress in adverse circumstances as well as greater benefits from supportive environments) is essential for addressing both the potential advantages and risks for children who are highly reactive to the environments in which they live. (See section on *The Science of Individuality*) (Cantor et al., in press).
- Understanding the scientific indefensibility of bureaucratic boundaries that separate the early childhood period (birth to age 5) from the K-12 school years is essential for designing and implementing more effective educational policies and programs. (See section on *Individual-Context Relations Across Development*) (Osher, et al., in press).
- Understanding the importance of active skill-building for parents and teachers is a critical

prerequisite for promoting the learning and development of children facing significant adversity. (See section on *Intergenerational Transmission of Adversity and Assets*) (Osher, et al., in press).

The National Scientific Council on the Developing Child, currently based at the Center on the Developing Child at Harvard University, has been engaged in the process of knowledge synthesis, translation, and communication for 15 years. Although its focus has been on the early childhood period, its experience offers a rich source of lessons learned for the broader SoLD agenda (Center on the Developing Child at Harvard University, 2014). Launched in 2002, its membership was drawn from two pre-existing initiatives. The first was the National Academy of Sciences Committee on Integrating the Science of Early Childhood Development, which produced a widely-cited report in 2000 entitled, *From Neurons to Neighborhoods: The Science of Early Childhood Development* (Shonkoff & Phillips, 2000). The second was the MacArthur Research Network on Early Experience and Brain Development, which was established in 1998 to catalyze interdisciplinary thinking and collaborative research at the intersection of neuroscience and developmental psychology. Although the mission of each included a broad dissemination agenda, the creation of the National Scientific Council was motivated by the belief that a coordinated effort would augment the impact of both.

Over the ensuing 15 years since its inception, a signature feature of the Council's well-documented impact has been its ability to build and sustain a small number of strategic relationships that complement its scientific expertise. The first is the seamless integration of rigorous communications research through a continuing partnership with the FrameWorks Institute, an independent, not-for-profit organization that has pioneered a distinctive approach to identifying, translating, and modeling relevant scholarly research to frame the public discourse on social problems (Shonkoff & Bales, 2011). The second strategy has been embedded in a direct pipeline to state-level policymakers in the United States through longstanding partnerships with the National Conference of State Legislatures and the National Governors Association Center for Best Practices.

Among the lessons learned by Council members, particularly over the last several years, is the recognition that accurately translated science is communicated most effectively by employing a variety of formats that speak to the varied preferences of selected audiences. In an age of multiple media options beyond the dissemination of written materials, successful knowledge brokers use all available modalities in order to reach people who have a range of different learning styles and preferences for accessing information. As the challenge of information overload continues to increase, the ability to communicate the multidimensional science of learning and development in a clear and concise story through a variety of formats and channels will be a powerful force for informing new policies and practices that will make a measurable difference in the lives of all children.

Making science usable

As the science of early childhood development has become more accessible to policymakers and practitioners across a wide range of fields, an increasing number of decision-makers have been asking, "Now that we understand the importance of the early childhood years for healthy brain development, what can we do with that knowledge? How should we change our current policies and practices to produce stronger returns on our investments?" Clearly there are no simple answers to these questions, but being able to provide an actionable response is a critical next step toward applying scientific knowledge in a way that produces increased benefits for children and their families who are experiencing difficulties.

A recent document from the Center on the Developing Child sums up 15 years of translated science and half a century of early childhood program evaluation data, followed by a call to action for generating and testing new, science-based, intervention strategies (Center on the Developing Child at Harvard University, 2016a). In response to readers who requested even greater specificity and concise usability, combined with early efforts to test and learn from different ways of using these principles in the field, the Center produced two shorter papers created in collaboration with active policymakers. The first extracted three key, scientific principles and applied them specifically to challenges facing the child welfare system (Center on the Developing Child at Harvard University, 2016b). The second positioned those same three scientific principles as a tool that policymakers and practitioners can use to evaluate any new or existing policy approach to make it more consistent with what is known about healthy development (Center on the Developing Child at Harvard University, 2017).

Given their importance and grounding in widely accepted scientific concepts, it is not surprising that three of the five science-based themes identified earlier

in this commentary also serve as the basis for the design principles that change agents across sectors can use to promote the learning and development of children growing up in a wide diversity of settings. These principles include: (a) support responsive relationships between children and the important adults in their lives; (b) strengthen core life skills; and (c) reduce sources of stress in the lives of children and families.

At the individual level, interventions can focus on targeted skill-building for children, parents, and teachers. At the human services level, practices can focus on the critical role of relationships in promoting healthy development, supportive parenting, and economic productivity. At the systemic or societal level, policies can emphasize reducing sources of stress that create lifelong challenges for children and make it difficult for adults to thrive as parents and bread-winners, or in their roles as educators or providers of a variety of services.

Operationalizing the application of these design principles can take many forms. The following are three potential pathways, as described in the previously referenced document (Center on the Developing Child at Harvard University, 2017):

- ***As a subject of inquiry about current policies and practices***. To what extent do current policies and practices promote (or hinder) responsive relationships and the development of core capabilities? To what extent do they diminish (or increase) sources of stress? What is preventing us from doing better? Focused observations and conversations at the front lines could elicit important information about how things work currently as well as suggestions for how they might work differently in the future.
- ***As a set of tests applied to proposed changes in policy or practice***. Compared to current practice, how might the changes under consideration be examined beyond questions about efficiency and cost-benefit assessments? How could we focus attention on their potential effects on promoting responsive relationships, developing core capabilities in both adults and children, and reducing sources of stress? Given those potential impacts, how strong is the case for (or against) the changes as currently envisioned? How might existing proposals be modified in order to produce more positive effects and/or fewer negative consequences?
- ***As an organizing framework for developing new policies or program strategies***. Making use of what has been learned from observations and conversations with educators and students, leaders might ask questions like: Suppose we want our system to do the best possible job promoting responsive relationships between teachers and children, between teachers and parents, and among the full range of staff within a school community. How would we redesign the system to make that happen? What are the manageable, incremental changes we might adopt quickly to get underway and what are the larger and more complex changes that we might aim for over time?

Understanding the major influences on learning and development is critical for improving life outcomes for all children. The design principles described above may or may not be the best (or only) ones to drive the SoLD action agenda. But any successful change strategy will require a disciplined approach to defining the challenge to be addressed, distilling implications from scientific knowledge that are acceptable and usable, and engaging key stakeholders in generating their own ideas and solutions.

Leveraging science to drive innovation

If more policymakers and practitioners were able to use scientific principles to shape systems and services in a way that is more supportive of healthy development, large numbers of children and communities would benefit. Nevertheless, the gap remains distressingly wide between the *outcomes* achieved by current best practices—even those that are aligned with the science—and truly transformative change in improving the life trajectories of children facing the greatest adversity. Clearly, the time has come to move beyond the use of science to explain *why* current programs are worthy of support and begin to leverage its power to address the more complex question of *how* we can produce larger impacts and sustain them at scale. In order to advance this agenda, the field of education must adopt a research and development (R&D) mindset and the kind of entrepreneurial spirit that supports risk-taking, breaks down barriers to change, develops and tests new ideas, promotes rapid-cycle learning, and builds on both successes and failures in the relentless pursuit of breakthrough outcomes.

The frontiers of discovery in the biological and behavioral sciences offer a remarkable opportunity to catalyze enhanced theories of change and design more effective strategies to reduce the consequences of adversity in childhood. Complementing other important work that is currently being done in the domains of quality improvement, staff development, and system building, a science-based, R&D approach is needed to inform a more diversified portfolio of investments that will produce substantially larger impacts than previously achieved at a population level.

The bold vision of the SoLD initiative presents such an opportunity. At a relatively simple level, breaking down the barriers between K–12 and early childhood education to build a stronger foundation for long-term, school success could be driven by a unified science of brain and behavioral development that extends from infancy to adolescence. A more ambitious effort to incorporate developmental biological thinking into an expanded evidence base to support learning across the childhood years could catalyze a rich array of promising, new initiatives. Advances in neuroscience and epigenetics could be mined to elucidate underlying causal mechanisms that might explain why specific teaching strategies achieve beneficial outcomes for some children and not others. Enhanced theories of change and science-informed hypotheses could stimulate the design, testing, and implementation of a new generation of intervention strategies for children with a wide diversity of learning styles, the impacts of which will far exceed the magnitude of those achieved by current best practices (Shonkoff & Fisher, 2013; Shonkoff & Levitt, 2010).

- As noted by Osher, Cantor, et al., "The personalization of context is perhaps the most powerful means at our proposal to promote the potential—neurobiological, physiological, social, emotional, and cognitive—in all children" (Osher, et al., in press).

Asking more nuanced, science-informed questions to elucidate the complex interplay between constitutional and environmental contributions to individuality could produce game-changing influences on the field of education and transformational impacts on the lives of millions of children.

The Center on the Developing Child at Harvard is engaged in building strategic partnerships to co-create a science-based R&D platform for the early childhood field. Beyond its focus on young children and their families, this effort is generating multiple lessons that could be applied across the school-age years as well. Meeting this challenge begins by bringing together many sources of knowledge, including data from methodologically rigorous intervention trials, causal understanding from developmental biology, the technical skills of implementation science, practical expertise from service providers and delivery systems across sectors, and on-the-ground insights from community leaders and service recipients. The model driving this work is characterized by precision in program development and measurement, a rapid-cycle approach to improving services, and a relentless focus on identifying what works best (and least or not at all) for whom, why, and in what contexts. These principles are viewed as equally applicable at the program, system, and policy levels (Center on the Developing Child at Harvard University, 2016a).

Central to this new way of working is the need to rethink the conventional definition of an "evidence-based" program, which is based on a statistically significant difference *on average* between a measured outcome in a group that received an intervention (which often includes multiple components that are not defined precisely) and that same outcome assessed in a control or comparison group. The science of learning and development challenges the "real-world" utility of this approach. Assessing program effects on average misses what may work exceptionally well for some and poorly or not at all for others. Attempting to create a single "does it work?" test for a multi-faceted or imprecisely defined intervention obscures its active ingredients, leaving only a "black box" that must be adopted in its entirety. The compelling need for a higher level of precision and segmentation in program design, implementation, and evaluation requires a more differentiated set of questions:

- *What about the program works?* If we understand the active ingredients, we are better able to replicate and scale them.
- *How does it work?* Being specific about the underlying mechanisms can help us increase the impacts and assure they will be sustained when a program is replicated in other contexts.
- *For whom does it work and for whom does it not work?* When we know more about who is and isn't responding, we can scale what works for the former and make targeted adaptations for the latter.
- *In what contexts does it work?* If we specify and understand the context in which an intervention was implemented, then we are better able to adapt it for other settings.

Resource allocation that relies exclusively on evidence of documented effectiveness in large-scale trials significantly reduces the opportunity to try new strategies. A more diversified portfolio of investments, with a mix of "blue chip" programs and high-risk options, could include promising, untested strategies informed by rigorous research on developmental processes and their underlying neurobiology, as well as field-based studies that generate intriguing hypotheses derived from high-quality quantitative and/or qualitative data. The proposition that the physiological consequences of excessive adversity call for interventions to reduce or mitigate the consequences of toxic stress is one such example of an alternative, "evidence-based" approach to program development. Policies that incentivize small-scale pilots, rapid-cycle

iteration, and a mindset that values both discovery and verification would also accelerate innovation.

Concluding thoughts

The articulation of an integrated science of learning and development has been thwarted by disciplinary boundaries and research silos as much as by disconnected policy and practice sectors. Research on early childhood development is typically separated from studies of middle childhood and adolescence; neuroscience from developmental psychology; animal models from human research; and bench science from application. The challenge and importance of creating a unified scientific framework from birth through the school-age years cannot be overstated and the two papers by Osher, Cantor, and their colleagues make a major contribution to this effort (Cantor et al., in press; Osher et al., in press). The central question now before us is not *whether* accessible and usable science and innovative thinking are important prerequisites to breakthrough impacts in the education of all children. The more compelling questions are: *How* can we activate a culture of science-informed innovation and nurture a spirit of constructive dissatisfaction with the impact of our current efforts? *What* will it take to reduce barriers to creativity? *How* can we increase incentives for change? *How* can schools, families, and communities work collaboratively to make all of this happen, especially for children whose learning styles and developmental needs are not being met by existing practices and systems?

These are the natural follow-on questions to those that appear at the beginning of this commentary and that motivate the SoLD initiative. Osher, Cantor, and their colleagues have produced a rich synthesis of an extensive knowledge base (Cantor et al., in press; Osher et al., in press). The opportunities to leverage this information to drive significant change in practice and policy are plentiful and the barriers to progress are formidable. The time to seize the opportunities and overcome the barriers is now.

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