

Neuroscience, psychology, and society: Translating research to improve learning

Allison Master¹ · Andrew N. Meltzoff¹ · Roberto Lent²

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Abstract This Introduction highlights the key point of this special issue on brain research, psychology, and learning. The issue discusses concrete ways in which neuroscience and experimental psychology, among other disciplines, can contribute to reducing educational inequities worldwide. The Introduction discusses common themes among the articles in this issue and outlines myriad benefits, as well as some unintended risks, of sharing scientific findings with educators and policymakers in order to induce educational change. The article also offers some novel ideas to help researchers bridge the gap between the science of learning and its implementation in educational settings, emphasizing the value of research-practice partnerships.

Keywords Brain · Education · STEM · Learning · Public policy · Science communication · Equity

Improving education is a universal goal. In 2015, the United Nations General Assembly adopted 17 sustainable development goals (SDGs), as part of the 2030 Global Agenda to end poverty, protect the planet, and ensure prosperity for all (UN 2015). SDG4 aims to ensure that quality education and learning opportunities are available for everyone. The International Bureau of Education (IBE) UNESCO works primarily to support this goal. Before we can achieve fair educational opportunities, however, we must first understand what quality education looks like and the best ways to improve learning. This understanding will derive from the joint contributions of scientists and educators. In this special

✉ Allison Master
almaster@uw.edu

¹ Institute for Learning & Brain Sciences, University of Washington, Box 357988, Seattle, WA 98195, USA

² Institute of Biomedical Sciences, Federal University of Rio de Janeiro, Av. Carlos Chagas 373, Ilha do Fundão, Rio de Janeiro CEP 21941-902, Brazil

issue, researchers offer their perspectives on bringing brain and psychological research together with education. The international researchers included in this issue represent neuroscientists, developmental psychologists, cognitive scientists, and leaders in the international research community.

The seven articles in this issue highlight diverse approaches to the study of learning, ranging from experimental studies with infants using magnetoencephalography (MEG), to correlational studies involving cortisol levels in preschoolers, to interventions to increase high school girls' interest in computer science. The levels of analysis range from the micro (synapses and neurons involved in learning) to the macro (the ecological context surrounding students).

Despite the diversity of perspectives in this special issue, many themes recur throughout. First, ironically, the only constant in education seems to be students' perpetual capacity for *change*. Students are relentlessly developing, changing, and growing. We see this in infant speech perception (Zhao and Kuhl) and the striking plasticity of the brain throughout life (Tovar-Moll and Lent; Lipina). This is, of course, good news. It means that educators have many ways to improve students' learning. These include targeting the cognitive abilities underlying mathematical achievement (Valle Lisboa et al.) and motivational factors such as persistence and interest (Master and Meltzoff). The strong potential for students to change supports the importance of scalable educational interventions. Large-scale interventions can improve academic outcomes for students worldwide (Master and Meltzoff; Ribeiro et al.; Valle Lisboa et al.).

The second recurring theme is the complexity of education. Education does not simply entail the emission of information from teachers but also involves—perhaps critically involves—issues about students' receptivity, readiness, and interpretation of the signals. Physiological factors such as sleep, nutrition, and exercise profoundly influence students' readiness for learning (Ribeiro et al.). Many aspects of the surrounding ecological environment can also set students up for optimal learning or impair their capacity (Lipina). For example, social cues and features in the environment can have a large effect on how engaged students are in learning (Master and Meltzoff). Interactions between students and teachers may even change teachers themselves (Tovar-Moll and Lent).

The third theme is the importance of high-quality educational opportunities and the issue of educational equity (D'Angiulli and Schibli; Master and Meltzoff). This matters most for students from low-socioeconomic-status (SES) backgrounds (Valle Lisboa et al.). These students often face more challenges than students from higher-SES backgrounds (Ribeiro et al.). There may be variations in the experiences of low-SES students that affect receptivity and interpretations of school lessons, and this influences outcomes (Lipina). Similarly, it is crucial both for equity and for maximizing innovation that we do a better job of providing opportunities in science, technology, engineering, and math (STEM) for girls and low-SES children (Master and Meltzoff).

The fourth theme is the importance of social interactions for education. Even for young infants, social skills and contexts are linked to language learning (Zhao and Kuhl). Social sensitivity is evident on a neural level as well, with functional synchronization of similar and different brain areas (Tovar-Moll and Lent). Moreover, the tendency to be attuned to social goals (those shared by others in a group) can be harnessed to boost students' motivation in fields like math and science (Master and Meltzoff). These social interventions to improve STEM have been shown to be effective as early as in preschool and are an exciting new development.

Organization of the special issue

In this international special issue, authors present the following articles:

- Allison Master and Andrew Meltzoff (University of Washington, United States) discuss how cultural stereotypes deter girls from STEM fields. They also describe interventions that can help increase girls' interest in STEM.
- Fernanda Tovar-Moll and Roberto Lent (Federal University of Rio de Janeiro, Brazil) describe how neuroplasticity forms the biological basis for learning. They outline how learning changes the brain on multiple levels—from neurons, to neural circuits, to networks of brain areas, to coordinated activation between multiple individuals.
- Christina Zhao and Patricia Kuhl (University of Washington, United States) describe the “sensitive period” for language learning during the first year of life, as well as an intervention showing that enriched auditory experience changes nine-month-old infants' speech perception (even on a neural level) during the first year of life.
- Sidarta Ribeiro, Natália Mota, Valter Fernandes, Andrea Deslandes, Guilherme Brockington, and Mauro Copelli (from the Federal Universities of Rio Grande do Norte, Rio de Janeiro, São Paulo, and Pernambuco, Brazil) describe how deficits in nutrition, sleep, and exercise (all more likely for students from low-SES backgrounds) can have physiological impacts on learning.
- Sebastián Lipina (Unidad de Neurobiología Aplicada, Argentina) discusses the importance of understanding the ecological context surrounding students. He describes how childhood poverty has biological consequences that can impact later learning through mechanisms such as stress and language exposure.
- Amedeo D'Angiulli and Kylie Schibli (Carleton University, Canada) describe a study examining cortisol as an additional measure of quality of early childhood education and care. Cortisol levels decreased (indicating lower levels of stress) in children and educators as daycare quality increased.
- Juan Valle Lisboa, Álvaro Cabana, Robert Eisenger, Álvaro Mailhos, Mario Luzardo, Justin Halberda, and Alejandro Maiche (Universidad de la República, Uruguay, and Johns Hopkins University, United States) describe an intervention in which Uruguayan children were given activities on tablet computers to improve their performance on the approximate number system. Children from low-SES backgrounds showed increased performance as they completed more trials of the intervention.

These articles encompass a wide range of topics, across diverse ages and cultures. They include both theory-driven research as well as more practical interventions to help low-SES children succeed. Despite this coverage, we are mindful of the fact that current research in brain and psychological science includes many additional discoveries that would also be helpful for policymakers, educators, and educational leaders such as principals. In the next section, we describe several key elements of the effective sharing of scientific discoveries with educators, with the aim of inducing other scientists to engage in translation from laboratory to practice and back, in a dynamic interaction.

The potential benefits and the possible risks of sharing new scientific discoveries

The research in this special issue illustrates the importance of “use-inspired basic research” (Stokes 1997). This is research that both (a) seeks fundamental scientific understanding and (b) can be used to meet societal needs. Sharing science beyond the ivy-covered towers can help policymakers and educators create evidence-based policies and practices that benefit students. The need for neuroscientists, cognitive scientists, experimental psychologists, and scientists of other disciplines to work together with educators is gaining broader acceptance as calls for interdisciplinary and translational research are increasingly heard. This is sometimes labeled “the science of learning” or “science for education”. Many international networks are occupied on this topic, including the OECD Learning Sciences and Brain Research Project (OECD 2007), the U.S. National Science Foundation Science of Learning program (National Science Foundation 2017), the Brazilian Network of Science for Education (SciForEd 2016), and other groups of interdisciplinary researchers (e.g., Meltzoff, Kuhl, Movellan, and Sejnowski 2009).

As an example of heeding the call for translational work, the Institute for Learning and Brain Sciences at the University of Washington shares cutting-edge findings about the science of child development with educators and policymakers. Notably, it has created online modules that contain movies and easy-to-understand summaries of hot-topics—many suggested by educators—such as brain development, bilingualism, dyslexia, social-emotional understanding, and equity. These modules are free resources that link researchers, educators, and policymakers worldwide, allowing users to download items from the library and to request that researchers address new topics of practical consequence (<http://modules.ilabs.uw.edu/outreach-modules>).

Why is it important for practicing scientists and educators to share knowledge? Such partnership can improve the efforts of both groups to make a difference in the lives of students. Scientific findings can help educators choose more effective ways to teach their students, including recognition of the many social and emotional factors that influence learning and cognition. Educators can also provide insights to researchers on classroom dynamics and assessment challenges, and suggest new directions and priorities for experimental studies.

Yet, such interactions and collaborations between educators and research scientists are not as common as they could be. Allison Master was inspired as an undergraduate student to pursue psychology as a college major after learning that rewards *undermine* intrinsic motivation (see Lepper, Greene, and Nisbett 1973). She was surprised that many practitioners did not use this information when trying to motivate their students. Efforts to bring together researchers and educators still remain less common than desirable. Further, many myths about neuroscience and learning have unfortunately become common among educators internationally. These include the myth of fixed “learning styles” and right-brain/left-brain dichotomies (e.g., Howard-Jones 2014; Kirschner and van Merriënboer 2013). Bringing together researchers and educators to share knowledge, and to create new knowledge, can help to correct these myths.

Researchers face many steps before their scientific findings are ready to share with the public (see Figure 1). These include translating scientific findings for a nonscientific audience so that knowledge is captured in an accurate and useful fashion as it travels from lab to world and back again. To illustrate, we start below with examples of work in the

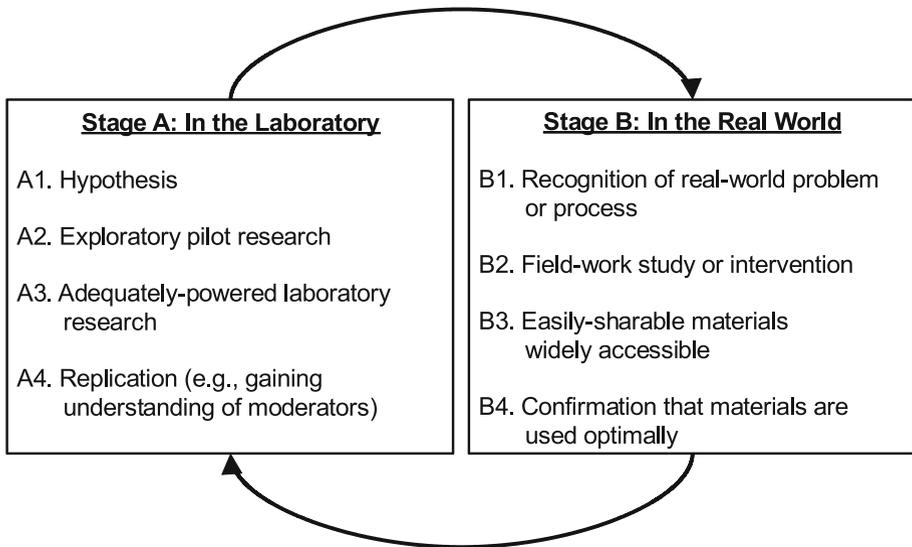


Figure 1 From lab to practice and back again

Note: This is a bidirectional loop connecting the laboratory and real-world application. We describe research first in the text, but we do not mean to imply a one-way, trickle-down model. In the lab (or test site), researchers establish increasing support for a hypothesis through experimental studies. Educators often inspire research questions. Researchers may test their methods in classrooms and make effective materials widely accessible. Feedback from educators and collaboration between researchers and practitioners can be valuable in each step of the process.

lab—but we fully acknowledge that many transformative ideas flow in the opposite direction, with real-world educational problems or solutions influencing research.

For simplicity and the purposes of illustration we start with an example of “use-inspired” (Stokes 1997) laboratory research. Effective research often begins with a good hypothesis (Step A1). Initial pilot studies eventually support this hypothesis (Step A2). Next, (ideally, statistically well-powered) laboratory studies add strong support (Step A3), and the hypothesis then transforms into a more solid, evidence-based theory. Further studies, which help clarify the mechanisms involved, then (hopefully) replicate these findings (Step A4). The theory may involve moderating contexts in which effects are stronger or weaker.

Some research never finds its way out of the laboratory, but many researchers have moved their research into the real world. This may involve recognizing processes or problems in real classrooms (Step B1), and then conducting fieldwork studies or interventions (Step B2). In these steps, researchers often study the methods used by effective practitioners. To reach the public, researchers and educators must then make their materials and curricula widely accessible (Step B3). A final—and too easily overlooked—step is to confirm that materials are interpreted as intended and used optimally (Step B4).

This entire process is difficult, with many opportunities for challenges and setbacks along the way. Some research that is effective in the laboratory requires continuous involvement from expert researchers; this makes it difficult to translate on a large scale. The real world is also complex and heterogeneous. Researchers need to test methods in different contexts to ensure that they remain effective (Paunesku et al. 2015). Challenges can also come when researchers and educators have different priorities and senses of

urgency about when research is ready to be used in the classroom. It is also important to build a feeling of trust and common ground when creating researcher-practitioner partnerships (Coburn, Penuel, and Geil 2013).

Two-way interactions can accelerate this process. Educators have a rich history of experiences and interactions in the classroom and can help identify meaningful topics for research. Educators are also crucial in helping researchers know what works and what does not in the classroom. The success stories of accomplished educators have inspired innovative research questions. For example, Jaime Escalante (whose story became widely known in the movie *Stand and Deliver*) used high standards and intensive support to help low-SES students succeed in AP calculus (Mathews 2010). Similarly, Uri Treisman's calculus workshops, which emphasized high expectations, were developed from his experiences in the college classroom (Hsu, Murphy, and Treisman 2008). Researchers later experimentally tested and confirmed the benefits of communicating high standards and support to students (Yeager et al. 2014).

We also highlight the importance of the final two steps of this process for researchers (Steps B3–4). If researchers aspire to make a difference in the real-world education of students, efforts to share findings do not end with a journal publication. Instead, their contribution can continue with thoughtful consideration of the best ways to effectively translate and disseminate those findings. There are many ways to communicate research findings to educators and the public, and some are more effective than others (Bales and Gilliam 2009). Researchers have the responsibility to share actionable findings in clear ways, which accelerates uptake and effectiveness. It is also possible that people will misinterpret research findings. In this case, we urge researchers to work to correct misunderstandings. For example, Carol Dweck, a scientific researcher whose research on mindsets has made an impact, wrote a piece to correct the “false growth mindset” (Dweck 2015). These corrections are particularly important when we use scientific findings to inform public policy, which has the potential to affect students on a large scale.

Conclusions

We applaud the IBE and *Prospects* for their efforts to integrate brain science, psychological science, and education for a worldwide audience. We hope to see more such synthetic publications in the future that can help to “spark change” in education. Social psychologist Kurt Lewin argued there should be “no research without action, and no action without research” (Franzoi 2007). We must share laboratory research so it can help children learn in both formal and informal settings. At the same time, researchers must listen to educators' experiences, to ensure that future research is effective and meaningful in real-life contexts. It is important for both scientists and educators to make informed choices to improve student learning. It is vital to bridge the gap between the science and the practice of learning.

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Allison Master (United States) is a research scientist at the Institute for Learning & Brain Sciences at the University of Washington. She has a BA from Yale University and a PhD in developmental psychology from Stanford University, and she completed a postdoctoral fellowship at the University of Washington. Her research interests include the effects of societal stereotypes on girls’ motivation in STEM, growth mindsets, the power of social connections and social identity to boost children’s motivation, and educational interventions.

Andrew N. Meltzoff (United States) holds the Job and Gertrud Tamaki Endowed Chair and is the codirector of the Institute for Learning & Brain Sciences at the University of Washington. He received his BA from Harvard University and a PhD from Oxford University. He is the coauthor of two books about early learning and the brain: *The Scientist in the Crib: What Early Learning Tells Us about the Mind* (Morrow Press, 2000) and *Words, Thoughts and Theories* (MIT Press, 1997). Dr. Meltzoff is a fellow of the American Academy of Arts and Sciences. His research interests include infant development, cognitive neuroscience, children’s stereotypes, in-group favoritism, and STEM outcomes. Dr. Meltzoff’s applied work seeks to build interdisciplinary bridges between psychological science and education.

Roberto Lent (Brazil) received his MD and PhD degrees at the Federal University of Rio de Janeiro, and he is currently a full professor at the Institute of Biomedical Sciences (ICB) of that university, of which he

served as director for the last eight years. He is a full member of the Brazilian Academy of Sciences and current coordinator of the Brazilian Network of Science for Education (CpE). His research interests involve neuroplasticity in humans and in animals, by combining tract-tracing imaging techniques in the former with histological, immunocytochemical, and axon-tracing techniques in the latter.