

Advancing Research on Learning Variability

Research Agenda

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Abstract

Variability is the hallmark of children's development and learning. Individual children vary over time and across domains of functioning (within-person variability); groups of children learning together have different skills, behaviors, and characteristics (within-group variability); and children are expected to operate successfully in a world of divergent and ever-changing contexts (contextual variability). Yet educational systems rarely take into account these different types of variability. Research, likewise, can do much more to embrace learning variability across the subfields of learning and development. If education systems are to address children's varied and changing needs, the research community must build on what is already known about population variability, child development, and learning to vastly expand our understanding of how children change and differ in learning settings, and how they can prepare to thrive in the multitude of contexts they will encounter throughout life.

This document was developed by the Jacobs Foundation with input and feedback from more than 50 experts on learning and development. This research agenda is intended to establish a scientific basis for designing education systems and programming that consider variability, and to support a multidisciplinary research community that seeks to improve children's learning and development globally. The agenda will be used by the Jacobs Foundation as a guiding framework for its research work and to serve as a public resource to inspire conversation among researchers and research funders on supporting and embracing learning variability in child development and education.

Introduction

Learning Variability

Childhood is full of encounters with learning variability – inconsistency within one’s own behavior, diversity within peer learning groups, and differences between the contexts one encounters each day. Yet in education, children often experience one-size-fits-all instruction that caters to a typical student rather than to the varied and multidimensional learners found in every classroom.¹ Education systems continue to prioritize standardized instruction and outcomes over paying attention to how children vary over time and contexts. This stands in the way of promising efforts to provide children with experiences suited to their skill levels and interests, or to offer individualized learning plans for neurodivergent students. As a result, too few children are given learning experiences that prepare them to fulfill their unique learning potential or to thrive in a variety of contexts, both now and in the future. In three decades of supporting cutting-edge, multidisciplinary research on child and youth development, the Jacobs Foundation has found that education systems across the globe fail to adequately address children’s individual needs or to take into account the multidimensional factors that shape learning.

The Jacobs Foundation embraces learning variability and invests in the creation of learning environments, experiences, and ecosystems that adapt to children’s various and changing needs and equip all children with the knowledge, skills, and qualities they need to reach their full learning potential.² This investment starts with research. Scholars are learning more about how cognitive, social, and emotional development are influenced by genetic, cultural, and environmental factors and about epigenetic processes, providing greater insight into what and how well children learn in a given situation. They are expanding our understanding of how variability in learning groups is rooted in prior gene-experience interactions, as well as how that variability is influenced by the current learning context; this knowledge can contribute to the design of learning experiences. Moreover, researchers can play a critical role by providing policymakers, educators, and designers with the rigorous scientific evidence they need to make practical decisions. In this context, scholars should embrace the study of learning variability across the subdisciplines of learning and development research, in particular by addressing three types of multidimensional variability: within learners, within groups of learners, and across contexts. A thorough understanding of variability in development and learning will enable us to provide better learning experiences and support children in reaching their full potential as dynamic individuals in a changing world.

Current research on learning and development still favors methods focused on short snapshots of time, group averages, and single environments, ignoring the variability that exists within a single individual over time, between people, and across contexts. Even when researchers across disciplines recognize that learning variability exists, they disagree about its origins and significance, how to address it, and when it should be embraced and when attempts should be made to reduce it. Over multiple decades, research on individual differences has flourished in explaining and describing differences between people; however, it should devote more attention to the social and institutional causes of individual differences, for example looking at how political conditions may affect groups differently. When it comes to addressing variability in learning groups, there is evidence that both adaptive personal technologies and adaptive group instruction can be effective, but less attention has been given to exploring for whom, for what purpose, and in what combinations these might be appropriate. Some disciplines focus on eliminating within-group variability, while others seek to embrace it. However, little attention is given to determining when variability may be beneficial or detrimental to a learner or group of learners. Failing to focus on understanding and addressing variability leaves us with fragmented, incomplete insights that are ill-suited to solving some of the hardest problems encountered when seeking to help all children to learn.

¹ For a compelling examination of the history, importance, and opportunity of learning variability, see Todd Rose’s 2016 book *The end of average: How we succeed in a world that values sameness*.

² “Potential” or “full potential” refers to the genetic makeup of a person and its desired epigenetic realization over time. The potential of an individual can only be approximated because it is an integral over many functions whose optimization through contexts over time is not yet understood.

In order to address children’s varied and changing needs and significantly improve learning and development outcomes, learning systems need to be created that are rooted in an understanding of variability within learners, within groups, and across the contexts learners encounter on a daily basis and over time.

The Jacobs Foundation invests in research in this area because we believe that advances in fundamental knowledge of variability will give rise to more research-based, variability-focused innovations; these, in turn, will lead to scaled interventions, environments, and ecosystems that will help all children to fulfill their potential. Over the next 8–10 years, the Jacobs Foundation commits to supporting research on learning variability in healthy, typically developing children between the ages of 2 and 12 in high-, middle- and low-income countries, through grantmaking and other research programming. These efforts will be guided by the present research agenda.

The Research Agenda

The Research Agenda is a set of themes and questions to guide research on learning variability within children, within groups, and between contexts, focusing on children between the ages of 2 and 12. The foundation will use the agenda to inform its funding decisions and to inspire collaboration and investigation of learning variability within the developmental and learning sciences. This research agenda is a statement of key priorities for the foundation, not a literature review or a technical paper. It accompanies the Jacobs Foundation 2030 Strategy, which has committed 500 million Swiss francs to advancing education in the period between 2020 and 2030.

This document begins with goals and context, which are followed by a description of the process by which the research agenda was created. We then list the relevant themes and questions and outline priority research approaches. Finally, we lay out a set of transformative, potentially high-impact topics for the foundation and others.

Goals and Use of the Agenda

The research agenda seeks to achieve certain goals for external impact and objectives internal to the foundation.

External Impact. **The goal of the research agenda is to build a scientific foundation for variability-based education systems and programming. Furthermore, it is our intention that the researchers supported by this agenda will form the backbone of a larger, multidisciplinary research community focused on issues of learning variability and working toward improving children’s learning and development globally. Finally, we hope that this research agenda, as an open resource for like-minded organizations and individuals, will inspire broader conversation and action among researchers and funders aimed at understanding and embracing learning variability in child development.**

Foundation Objectives & Use of the Agenda. Within the foundation, the agenda will be used to inform resource allocation decisions, especially within the Learning Minds Portfolio, whose flagship programs include a research fellow program and a bi-annual conference. It seeks to meet the foundation’s objectives as a research funder:

- Providing funding for contemporary science and promoting scientific freedom, raising public awareness of the value of science, and connecting research and practice.
- Pursuing an open, public-goods-driven research agenda that serves the foundation’s thematic focus and allows external individuals and organizations to work on specific topics, either independently or partnering with the Jacobs Foundation.
- Maintaining the Jacobs Foundation’s position as a funder of state-of-the-art research.

Embedding the Research Agenda in the Work of the Jacobs Foundation

This research agenda most closely reflects the work of the Learning Minds portfolio, one of three portfolios that are devoted to the Jacobs Foundation's mission of understanding and embracing variability so that all children can realize their learning potential. The Foundation has a 30-year history of supporting state-of-the-art research on learning and development. The Learning Minds portfolio nurtures a multidisciplinary community of the most innovative researchers, with a view to strengthening the global research and evidence base and helping to shape the future of learning and development. Its current aims are:

1. To promote breakthrough scientific research on learning variability, thereby unlocking the potential of new pedagogies and technologies that embrace children's individual differences and preferences. In so doing, to enable more children to access the learning experiences they need to reach their full learning potential.
2. Through increased cross-sectoral, multi-disciplinary collaboration, to catalyze new scientific opportunities and shape the future of learning and development.

Complementing the Learning Minds portfolio are the Foundation's Learning Schools and Learning Societies portfolios. They focus on promoting evidence-based practices across the global school system, as well as embedding evidence into national education policy, respectively. For its part, the Learning Minds portfolio remains focused on research seeking to understand the mind of the child, rather than on investigations of aggregate or community-level outcomes or group differences. Accordingly, although we acknowledge that education systems and structures are powerful levers for addressing learning variability in the school system, much of the research that is devoted to systems and structures is outside the scope of this research agenda and is the focus of the foundation's forthcoming translational research efforts directed at influencing school-level practice and government policy.

Research Agenda Compilation Process

As we drafted the research agenda, we benefited from ideas and feedback from more than 50 scholars in the fields of human learning and development. The first draft was based on a set of interviews, conversations, and literature reviews commissioned by the foundation, as well as a review of existing research agendas³. Eleven scholars subsequently convened over two days to discuss transformative research and provide general feedback. In its final form, the agenda reflects their recommendations and a vetting process conducted in consultation with Jacobs Foundation staff, board members, and key stakeholders in the research community.

³ Ideas from the field were collected via the following:

- 35 interviews with scholars in the disciplines of psychology, neuroscience, education, and economics. Interviewees were asked to name research topics and challenges that would advance our understanding of variability and how to embrace it over the next 8–10 years.
- Discussion with ~20 scholars in the fields of learning and edtech at the Jacobs Foundation EdTech meeting, May 2022.
- 5 commissioned "rapid reviews" of literature. Reviews included open research questions for each topic.
 - Addressing Learning Variability Through Personalization, by Leonard Tetzlaff and Garvin Brod
 - Learning Variability and Motivation in Ages 2–12, by Lisa Bardach
 - Addressing Learning Variability Through Social Learning Approaches, by Sunny Avry
 - How Can Developing Countries Address Heterogeneity in Students' Preparation for School?, by Alejandro Ganimian and Sharnic Djaker
 - Learning Variability and Executive Function in Ages 2–12 in the Global South, by Ishita Ahmed
- Review of existing research agendas: How People Learn II: Learners, Contexts, and Cultures (2018); the National Commission on Social, Emotional, and Academic Development: A Research Agenda for the Next Generation (2018); Learning First: A Research Agenda for Improving Learning in Low-Income Countries (Wagner & Murphy, 2012).

When we began drafting the research agenda, we knew its contribution to the field would be most significant if we gathered input from a variety of scientific disciplines in defining priorities, rather than pre-determining a framework or a set of subtopics. Accordingly, we intentionally sought a diverse range of perspectives, including the views of researchers who study children from infancy through adolescence and of scholars who focus on development, learning, or schooling, and using methods ranging from learning analytics to intervention design to neuroimaging. All told, we considered input from the fields of psychology, education, sociology, economics, computer science, neuroscience, and public policy. In all interviews and commissioned reviews, we posed this broad question: “What are the most important questions, topics, and challenges that will enhance the world’s understanding of learning variability over the next 8–10 years?”

Following this open-ended inquiry, the final research agenda was formulated to meet three criteria and answer related questions: (1) It should promote the rigorous scientific pursuit of foundational knowledge on learning and development. If an agenda item were completed, how crucial would the knowledge gain be? (2) It should encourage research with practical significance for children’s learning and development. Will the research ultimately – whether in one year or thirty – lead to more effective experiences, materials and tools, or ways of thinking in the area of learning and development? (3) It should embody the Jacobs Foundation’s values of promoting scientific freedom, communicating effectively as a public good, and supporting state-of-the-art research.

Research Agenda Overview

At the core of the research agenda are questions and topics with the potential to advance our understanding of learning variability over the next 8–10 years. In addition, interviewees encouraged us to emphasize the importance of how research is done. Certain ways of thinking about or conducting research can play an important role in carrying out scientifically rigorous investigations of learning variability and achieving a practical impact. We identified a set of Priority Research Approaches, described below, for the Jacobs Foundation to consider when making funding decisions, with a view to supporting research at the frontier of scientific contribution and impact.

Research Agenda Topics: Learning Variability Across Time, People, and Contexts

There are three categories of learning variability: *within-person*, *within-group*, and *contextual*. *Within-person variability* refers to how a single person changes within and across skills, characteristics, and behaviors. Children behave inconsistently over time and across skills. Why is this, and how can this variability be influenced in a productive way? *Within-group variability* refers to differences between the people in a group, for example the students in a third-grade classroom. Children live and learn in a social world with a variety of other people. How can we ensure that their needs are met in group learning situations? *Contextual variability* refers to the many different contexts children encounter throughout their day and lifetime. Children learn across many environments, as they move into a future marked by change. How can we prepare them for diverse contexts? These categories reflect the variability children experience in their day-to-day lives. They are the organizing themes for the research agenda, framing a set of high-level questions on how to meet the needs of all children across contexts and over time. In addition to the three variability themes, there is a category called *Designing for Scale*, which focuses on research into how learning programs might be adapted to work in different contexts. Finally, *Data and Methods* promotes advances in research methodology.

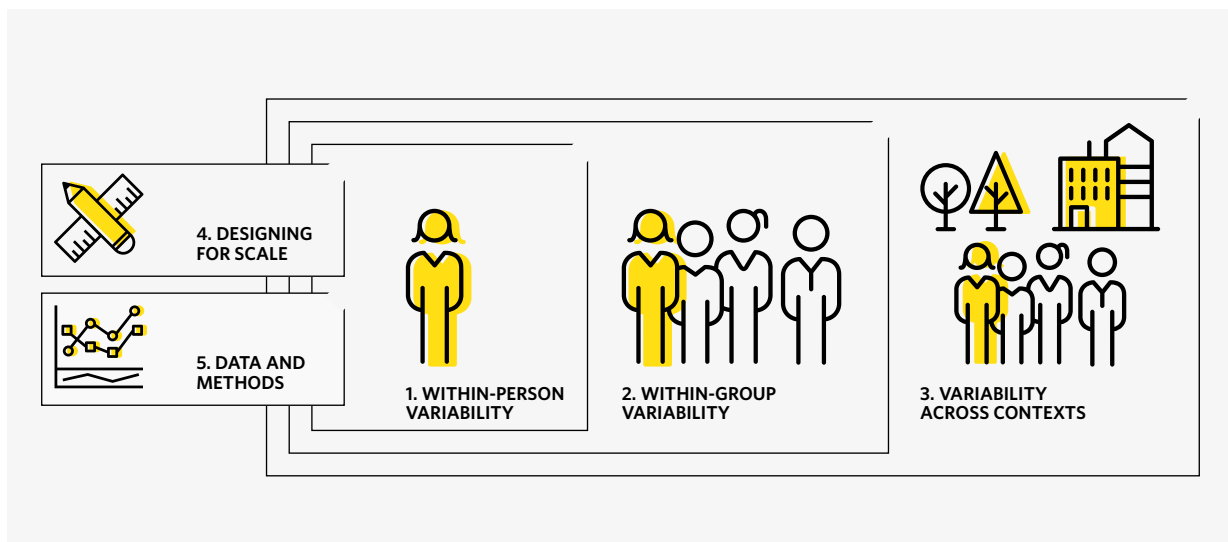


Figure. Five Themes: (1) within-person variability, (2) within-group variability, (3) variability across contexts, (4) designing for scale, and (5) data and methods

Aligned with the Jacobs Foundation’s 2030 Strategy, the research agenda prioritizes research on children ages 2–12 in the healthy, typically developing population. The foundation will continue to allocate resources in keeping with the principle of scientific freedom and with a view to promoting state-of-the-art science. In addition, it is committed to supporting research in low- and middle-income countries (LMICs).¹ Roughly 90% of children live in LMICs, yet these countries have historically been excluded from research on learning and development. As a result, much of what we have learned about human behavior has been derived from a small and unrepresentative subset of the world’s population. An increase in LMIC research will improve the field’s ability to generalize developmental and learning theories. This research may identify new foundational issues of learning and development that are apparent in LMIC contexts but less so in high-income societies. The foundation therefore welcomes investigations addressing all of the themes and questions in the research agenda in LMICs, and particularly in Colombia, Côte d’Ivoire, and Ghana, where the foundation has invested in other educational programs.

¹ For a review on addressing classroom heterogeneity in low- and middle-income countries, see Ganimian and Djaker, 2022.

Each theme is listed below, along with a relevant practical challenge. In each case we offer a list of questions designed to advance our understanding of learning variability. The best approach is usually to carry out multidisciplinary research that integrates traditionally separate areas. These questions encourage a close look at the dynamic interaction, over time, between the child and the context, which is best accomplished through longitudinal research. For examples, see Appendix A.

Theme 1: Within-person Variability

Understanding variation in skills, behaviors, knowledge, and characteristics over time.

Human behavior is not consistent from one point in time to another – a child may seem to understand the mathematical concept of place value one day, but not the next. While relatively high performance on one skill often predicts high performance on another, this is not always true. For example, a child who finds it easy to identify others' emotions may not bounce back easily from her own disappointment. Given this within-person complexity, how can educators, parents, or caregivers know what a particular child needs at a given moment? How will the child respond to a teacher's actions today, and how might she respond differently tomorrow? Research can help shed light on these practical questions by addressing questions posed in the research agenda:

- 1.1 Why do children show inconsistent behavior, skills, knowledge, and characteristics from one time point to the next? What explains such variability, and what is its developmental purpose? Answers to these questions may help educators and caregivers interpret children's behaviors – is a child performing erratically today because she didn't understand the concept she learned yesterday, or because trying out different behaviors helps her gain a better understanding in the long run?
- 1.2 When can learners perform at the upper end of their ability range, and what experiences or factors allow them to do so? Insights in this area are helpful in designing developmentally appropriate or learning-appropriate instruction for a specific individual in a given context.
- 1.3 How do children's characteristics, knowledge, and skills vary over time and at different ages? Answering this descriptive question will make it possible to identify clusters of developmental trajectories across children, allowing for the development of educational programming to meet the needs of each child.

Theme 2: Within-group Variability

Addressing and embracing heterogeneity in learning groups.

Children spend much of their time learning in social groups, such as daycare settings, classrooms, and formal or informal out-of-school learning experiences. They bring their own unique needs and experiences to these groups, which then influence how they learn and participate. In relatively homogeneous contexts, students in a classroom may have diverse interests but similar home lives, academic preparation, and expectations of higher education. In relatively heterogeneous contexts, students in a single classroom may span six grade levels.

How can a teacher teach heterogeneous groups of children in a way that meets their needs and fosters deep understanding of the subject matter? We highlight two promising pathways. First, teachers can engage a whole class at once in a manner that allows each child to participate fully, but differently, in learning activities, in keeping with their skills, proclivities, knowledge, and interests. Second, educators can employ level-based tutoring or groupings to ensure that children are challenged at the appropriate level. Programs such as [Teaching at the Right Level](#), for example, have had great success providing group-based instruction geared to students' academic level. Computer-based adaptive tutors, for their part, offer individualized instruction in the form of solitary computer activities that continually adapt to students' performance. Determining which approach is most appropriate in a given situation, and why, can be challenging. The research agenda poses the following questions:

- 2.1 Social learning: How can group instruction in social environments like classrooms accommodate the needs of individual students while also taking advantage of learning variability to improve learning for the entire group?
- 2.2 Personalized learning: How can one-on-one learning experiences be designed to accommodate individual children's academic and nonacademic situations and promote development?
- 2.3 What classroom practices can accelerate the learning of lower-performing students while simultaneously maintaining or accelerating the learning of higher-performing students?
- 2.4 Teachers: What can be done to encourage teachers to embrace variability in a group learning setting, such as a classroom, and address it most effectively?

Theme 3: Contextual Variability

Preparing children to thrive across contexts and time.

Children encounter many learning contexts throughout their day – home, math class, their neighborhood, a playground – that they are expected to navigate. Over the years and decades, they will need to adapt to and shape the various contexts in which they find themselves. The flexibility to do so is essential for a child's long-term success in our rapidly changing world. However, educational settings are often designed to focus only on a child's learning goals within a specific setting (e.g., meeting first-grade proficiency standards for numeracy), rather than considering how children's current learning can, and should, promote future learning. Researchers can help us prepare children for life by answering several questions about learning across contexts and time:

- 3.1 What are the skills, behaviors, knowledge, and characteristics that prepare children to learn in the future, and how do those factors interact with one another and the given context?
- 3.2 How might we teach such skills, behaviors, knowledge, and characteristics?
- 3.3 How do we know when children are learning such skills, behaviors, knowledge, and characteristics, and are able to use them in different contexts?
- 3.4 The environment shapes how a child interacts and learns within it. How can we understand environments, and how can we facilitate children's successful adaptation within and across them?

Theme 4: Designing for Scale

Ensuring that learning solutions are effective across multiple contexts.

If expensive proof-of-concept learning experiences are scalable at modest cost, they can be change agents for many children. Yet scaled learning programs often lose their efficacy as they grow. For years, this was presumed to be largely a problem of implementation and making sure that the program was run as intended in different contexts. Now, with growing recognition that different people and contexts require different approaches, the challenge no longer lies in accurately copying a program as it is disseminated from place to place, but rather in adapting program elements to accommodate the commonalities and differences in various contexts.

This challenge has two parts: understanding why a program works for some children and not others, and in some contexts and not others; and finding ways to adjust learning solutions in a way that maintains their functional psychological mechanisms and program components in different contexts. Researchers in the field of learning and development play a prominent role by studying psychological mechanisms of learning and motivation, how children and contexts interact, and learning design. The questions below address issues of scalability and adaptability in designing a learning solution. Research on implementation and effectiveness is beyond the scope of this research agenda.

- 4.1 In a learning solution (i.e., an educational program), what mental processes or psychological mechanisms (e.g., curiosity, consolidation, connecting to existing conceptions of the world) are engaged to produce learning? What program components or “active ingredients” best stimulate these mental processes?
- 4.2 What environmental characteristics interact with a child’s experience of the mechanisms of a learning program, and how?
- 4.3 How does community-based research or inclusive design affect solution development and the potential for impact within and across communities?
- 4.4 To what extent are the social-emotional skills promoted in developed countries also conducive to learning in LMICs? What other skills (not currently studied in high-income countries) can help children to thrive in LMICs?

Theme 5: Data and Methods

Facilitating next-generation research, assessment, and broad application.

In the interviews and reviews conducted for this agenda, advances in data and methods were most frequently mentioned as potentially transformative. New methods of measurement and analysis allow researchers to track, understand, and intervene in complex systems, including systems that change over time, across multiple dimensions, and in response to internal and external input – such as a developing child. High-quality measurement is crucial for answering the questions raised in themes 1–4. The following questions allow for investigations within the prior four themes and highlight emerging opportunities related to data and measurement:

- 5.1 When studying the learning and development of children between the ages of 2 and 12, how can we make measurement instruments and practices more reliable, valid, and unbiased?
- 5.2 In the study of learning and development, how can different timescales enrich our understanding of within-, between-, and across-context variability?
- 5.3 How might new types of data (physiodata, interaction logs, sensors, wearables) at various levels of analysis – especially collected via practical, non-intrusive methods – provide new insights into multidimensional learning and developmental processes and outcomes?
- 5.4 How can classroom assessments (i.e., formative or process assessments) enable students and teachers to recognize and respond more quickly to within-student and between-student variability across multiple dimensions of learning and development?
- 5.5 What in-school research methods and assessments will help both practitioners and researchers to meet their practical and knowledge-related goals?
- 5.6 What new evaluation methods can provide more rapid feedback on the impacts and mechanisms of education programs in various contexts?

Through the themes and questions discussed above, we outline research needs concerning three types of variability that affect the lives of children: within-person variability, within-group variability, and contextual variability. We focus on the learning and cognitive development of children ages 2–12 across the globe, while also raising research questions that address the instructional skills and perceptions of teachers and parents (see Appendix A for more examples), who have enormous influence over children’s experiences.

In keeping with the focus of the Learning Minds portfolio, the agenda prioritizes investigations into the mind of the child, rather than investigations of systems and structures. Although we recognize that educational systems and structures have great potential to pose challenges in schools and societies related to learning variability, as well as to address those challenges, here we limit structural and systemic questions to those that focus on how such systems and structures interact with the minds of learners and educators. We refrain from looking at the role of education systems on aggregate outcomes that are only indirectly related to the mind of the child, such as average school attendance, teacher retention, GDP, or dropout rates. Furthermore, the work highlighted here is complementary to “what works” impact evaluations of educational programming, but does not include such evaluations.

It is our hope that the themes and questions raised in the research agenda will inspire research that is of both practical and scientific value and aimed at gaining a better understanding of learning variability. They are not comprehensive, nor representative of a consensus within the field. Rather, they are important questions within a much larger set of inquiries about how children learn and develop in a variable world. Answering these questions may make it easier for educators, program designers, and policymakers to take advantage of learning variability in order to provide better educational and developmental experiences for all children.

Priority Approaches: Promising Ways of Thinking or Doing

These **Priority Approaches** emerged from conversations with researchers. Some described the approaches as impactful for the field in general; others pointed out that funding novel approaches is a way for philanthropic donors to distinguish themselves from government and corporate funding institutions. It was noted that as a relatively smaller and more nimble funding source, philanthropy could achieve a lasting impact by supporting promising approaches to thinking or research that have yet to become fully established in the field.

Most frequently mentioned was the need for **Integrative Research** to forge productive connections across research traditions, for example between child development and learning, or between early-childhood and middle-childhood research focusing on similar topics. Next was **Contextualized and Generalizable Research**: Interviewees emphasized a need to pay more attention to the interaction between context and learner. Each learner is situated in a history, a culture, an identity, a developmental state, an environment, and a set of interactions, all of which contribute to the child's next stage of learning and development. Beyond simply acknowledging that learners exist in context, how should researchers take that fact into account in designing their research? Interviewees and reviews also urged the field to devote more attention to **Strengths-Based Learning** – reframing variability (between and within individuals) as a feature to be taken advantage of rather than as a challenge to be overcome.

The Jacobs Foundation may use the **Priority Approaches** as guidelines for prioritizing research proposals related to the agenda themes and questions. Prioritizing funding for these approaches would increase the likelihood that the Jacobs Foundation will continue to support state-of-the-art research, while relying on other types of funders, such as governments, to support relevant but more traditional studies.

Priority Approaches:

1. Integrative Research

To gain a better understanding of variability in development, this approach gathers evidence:

- a. across ages, specifically connecting early childhood with middle childhood
- b. across fields and disciplines, e.g., cognitive neuroscience and social psychology; machine learning and developmental sciences
- c. across timescales, e.g., moment-to-moment variations and long-term changes
- d. across levels of analysis, e.g., social and physical environment; behavior, and brain, with behavior as the central concept of interest; computational-level explanations and process models of behavior

2. Contextualized and Generalizable

Researchers seek generalizable knowledge by studying learners as individuals contextualized in

- a. various learning environments
- b. various relationships and interactions
- c. history, cultural norms, and identities
- d. their genome and epigenome

3. Asset-Based Learning as Strength

In a strengths-based approach, researchers view learners' current states (of knowledge, emotion, etc.) as opportunities to build upon, rather than gaps to fill. This prompts questions such as, "For students who are not native speakers of the school language, how can the characteristics of their home language be used to provide a foothold into the content domain?" instead of "In what ways do children's home language practices hinder their learning of standard academic topics at school?"

Transformative Questions

Finally, we wanted to spotlight the need to support Transformational Ideas in learning variability, in line with the Jacobs Foundation's commitment to funding state-of-the-art research. As one contributor noted, "The research with the biggest impact is the research that yields conceptual and paradigmatic change."

While it is impossible to predict which research will ultimately transform a field of study, transformation is more likely to happen if we engage in intentional inquiry into how an idea might change the way scholars in a field ask questions, consider their data, or interpret their findings. The following examples of Transformative Questions emerged from a two-day workshop with 11 scholars from a variety of subdisciplines of learning and development, who were tasked with identifying transformative questions and ideas within and across the five research agenda themes.

- T.1 **Can we develop a multidisciplinary ontology of learning contexts?** Currently, while academic disciplines typically recognize the importance of context and environment, they have not yet come to a common understanding of which features are salient for learning and development, as well as when, for whom, or why they matter.¹ This lack of a shared understanding of context is a barrier to transdisciplinary learning, holds back the broader science of learning and development, and makes it difficult to have meaningful conversations about learning variability, beyond a narrower focus on specific skills or children of a specific age. It also handicaps discipline-specific academic researchers who too often have "disciplinary blinders" that prevent them from seeing (or measuring) aspects of context that are not part of their disciplinary tradition, but that may matter for the phenomena they study. The very process of co-developing a unifying, multidisciplinary theory of context would greatly benefit the work of individual scholars. Knowledge gained from a specialized line of research could also lead to a broader understanding of context if there were an emerging, common schema onto which new information could be mapped. This would allow researchers studying the development of certain skills and domains and those investigating the power of particular aspects of context to communicate with one another, to apply lessons learned from other disciplines to their own work, and collectively to contribute to the emerging study of learning contexts.²
- T.2 **When is learning variability beneficial to learning and development rather than detrimental? When should we focus on reducing variability in group and individual settings, rather than leveraging that variability?** Researchers in different disciplines tend to think of within-subjects or between-subjects variability as either a feature to embrace or a challenge to eliminate. If we were, instead, to ask in what circumstances variability is beneficial to a child rather than detrimental, this would trigger a host of changes in the field of child development. Answering that question would require new tools to study specific constructs over time, leading to a paradigm shift in the study of children's development. By studying variability rather than trying to control it, researchers could gain new insights into development and learning. A fundamental question would have to be addressed: How can we define and measure within-child variability for different domains, contexts, timescales, and developmental periods? Carrying out this work would provide insight into how best to intervene to benefit individuals and groups (e.g., with whom, when, and how).³

¹ For example, a cognitive scientist may be primarily focused on the nature and benefits of the learning tasks in which a child engages in a learning setting. A social psychologist may pay more attention to how a child perceives psychological conditions or social interactions in the environment that trigger a sense of belonging or self-efficacy (or that cause the child to lack a sense of belonging and to conclude that trying is futile). An educational psychologist may be most interested in the nature of the relationship between a child and a teacher. A developmental neuroscientist, finally, may be interested in how changes in brain and behavior interact with any of these dimensions.

² Justification for T.1 was written by Camille Farrington

³ Justification for T.2 was adapted from a note from Julia Leonard

- T.3 **What methods might enable us to make individual-level predictions about future behavior across contexts?** The main goal of human psychology is to explain the causes of human behavior. While a focus on how constructs contribute to our actions is crucial to understanding the human experience, it does little to help educators or parents predict what children will do next or how they will respond to stimuli. Accurate behavioral predictions for individuals would require advances in multidisciplinary measurement, analysis, and theory, as well as integrating information on context, interaction, and psychological factors. Individual-level predictions would allow us to tailor learning experiences to children's needs and to conduct research on a variety of developmental and learning pathways leading to a specific outcome. In addition, it would no doubt encourage researchers to explore culturally relevant measurement and investigation as a way to improve predictive power in various communities.
- T.4 **How can we educate children for a rapidly changing future?** Preparing humans for an unknown future has long been the realm of futurists, science fiction writers, and the World Economic Forum, but not so much the focus of researchers studying development and learning. If those researchers could find ways to look systematically at how the future should affect what children experience today, they could mobilize the discipline to take a future-facing approach in educating all children for a rapidly changing world.

The potential for transformation lies in unlocking new ways of thinking about and adapting to learning variability, as well as in new methods, tools, and collaborations that encourage researchers to ask novel questions. These ideas extend beyond a single academic domain, and thus require multidisciplinary collaboration. The Jacobs Foundation plans to allocate resources to support cross-disciplinary discussion and research on a subset of the topics discussed above, while exploring possible avenues for supporting further transformation.

Conclusion

Learning variability is a hallmark of children’s day-to-day lives – variability within their own behavior, both within and across functional areas; diversity within the peer learning groups to which they belong; and variability in the contexts they encounter each day. Yet education systems and research in the field of learning and development rarely consider variability as a driver of instruction, policy, or research activities. We argue that if learning experiences were designed to take into account within-person, within-group, and contextual variability, then more children around the world would receive the support they need to achieve higher levels of functioning in key dimensions of development. A thorough understanding of learning variability, gained through developmental and learning research, would play an important role in facilitating the kinds of experiences children need in order to thrive. With this research agenda, the Jacobs Foundation offers a set of research questions and approaches to the field of early and middle childhood education – which encompasses educators, researchers, and funders – designed to spur productive conversations and collaborative projects focusing on learning variability. As a funder of science as well as impact programming in education, we believe that simultaneous investments in research and practice make both areas stronger. Accordingly, we will consider our research agenda and related activities a success if, by 2030, the global research and funding communities have increased their efforts to learn more about supporting learners through variability, and programs “on the ground” are designed to account for within-person, within-group, and contextual variability. We invite you to partner with us to advance the world’s understanding of learning variability and enable all children to achieve their full potential.

Appendix A: Illustrative Research Questions

This section lists example research questions for each of the three variability themes. These questions illustrate the breadth of research relevant to the question prompts but are not intended to be comprehensive. Through field input, they were found to be illustrative of the Priority Approaches as well as the concepts and topics that came up often in our interviews: motivation, self-regulation, agency, culture, and identity.

Theme 1: Within-person Variability

Understanding variation within and between skills, behaviors, knowledge, and characteristics over time.

- 1.1 Why do children show inconsistent behaviors, skills, knowledge, and characteristics from one time point to the next? What explains such variability, and what is its developmental purpose?
 - Ex.a. How might measurement tools be improved to ensure valid and reliable measurement of within-child variability over time?
 - Ex.b. What impact do contextual factors have on children's day-to-day variability in skills?
 - Ex.c. How do children's interactions in various relationships influence their expectations, interpretations, or motivations in future interactions? How does this vary with age and development?
 - Ex.d. Parents and families: How do cultural norms affecting how parents and adults view children and development affect children's multidimensional development over time?

- 1.2 When should learners perform at the upper end of their ability range, and what experiences and factors allow them to do so?
 - Ex.a. Teachers: How do teachers understand day-to-day variation in students' skills, and how do they tailor instruction to account for that variation? How might they come to understand within-person variability and provide optimal instruction?
 - Ex.b. Teachers: How might teachers best leverage a child's strengths in certain domains in order to promote learning in areas in which the child needs more support?

- 1.3 How do children vary in their multiple characteristics, knowledge, and skills over time and at different ages?
 - Ex.a. What are the relationships between a child's characteristics and skills over time and at different developmental stages?
 - Ex.b. What is the role of conscious meaning-making (e.g., what is happening here and what are the possibilities for me?) versus unconscious, patterned responses in explaining within-person variability?

Theme 2: Within-group Variability

Addressing and embracing heterogeneity in learning groups.

- 2.1 Social learning: How can group instruction in social environments like classrooms accommodate the needs of individual students while also taking advantage of learning variability to improve learning for the entire group?
 - a. How does the human ability to predict the intentions of peers and teachers (i.e., form expectations) influence learning interactions and outcomes?
 - b. How do motivational states emerge from learning interactions between children or between children and teachers? How do these states influence future learning interactions?
 - c. What are the psychosocial and academic impacts of shaping children's various strengths – cognitive and cultural – into learning experiences in group settings? How does this vary by age?
- 2.2 Personalized Learning: How can one-on-one learning experiences more effectively take into account individual children's academic and nonacademic states and foster their development?
 - a. In instruction, what is the optimal balance of building on children's strengths and correcting their weaknesses? How does this vary with characteristics such as age and the development of expertise (beginners versus experts)? How does this interact with children's sense of what is interesting and meaningful?
 - b. Under what conditions does tech-enabled personalization support self-regulated learning and social skills, and when does it interfere with development?
- 2.3 What classroom practices can accelerate the learning of lower-performing students while simultaneously maintaining or accelerating the learning of higher-performing students?
- 2.4 Teachers: What can be done to encourage teachers to embrace within-group variability in a group learning setting, such as a classroom, and address it most effectively?
 - a. How might teachers learn to adapt their instruction in real time to accommodate their students' diverse cognitive and emotional states?
 - b. How do incentive structures lead to changes in the behavior of teachers and principals? How can incentives systems encourage teachers and principals to address the needs of individual children in schools more effectively?
 - c. How can we help teachers orchestrate classroom learning as a blend of personalized individual experiences and group learning experiences?
 - d. How can we help teachers respond effectively to the abilities and cues of children of different ages?

Theme 3: Contextual Variability

Preparing children to thrive across contexts and time.

- 3.1 What are the skills, behaviors, knowledge, and characteristics that prepare children to learn in the future, and how do those factors interact with one another and the given context?
 - a. What are the neural and psychological mechanisms by which adaptive social and emotional skills affect a child's learning experiences?
 - b. How might children's self-identities (the strength and characteristics of their identities) have a positive impact on their success across contexts?
 - c. Where does motivation "live"? In the student, in the context, in the student's perceptions of context, in social interactions? How can we bring together research on group-level motivational climate, on differing student perceptions within a classroom, and on individual student perceptions?
 - d. How do general skills like cognitive flexibility and other executive functions promote or co-develop with a child's ability to learn and appropriately apply specific strategies?
 - e. When skills and behaviors are developed as adaptations to adverse contexts, what implications does this have for their future use in non-adverse contexts? And vice versa?
 - f. How do genetic, environmental, and epigenetic differences interact and covary to bring about changes in key aspects of development?

- 3.2 How might we teach such skills, behaviors, knowledge, and characteristics?
 - a. How can children learn to apply skills appropriately, in keeping with the context?
 - b. How should learning experiences for adaptive skills vary with the age or skill of the learner?
 - c. How might such instruction productively use students' various incoming identities, experiences, states, knowledge, and skills for adaptive skill learning?
 - d. Teachers: How can we help teachers understand and measure student learning and provide appropriate instruction so that students can thrive across contexts?

- 3.3 How do we know that children are learning such skills, behaviors, knowledge, and characteristics and are able to use them in different contexts?
 - a. How can we better measure what children are doing while learning in formal and informal learning environments?
 - b. How can we measure children's ability to learn, and not just their mastery of certain topics?
 - c. Can we make context*individual assessments that tell us something about other contexts in which a child might do well?

- 3.4 The environment shapes how a child interacts and learns within it. How can we understand environments, and how can we facilitate children's successful adaptation within and across them?
 - a. What unifying theories, generalized knowledge, and mechanisms can transform the mere description of context into a science of context?
 - b. In addition to developmental changes, what contextual differences between early childhood and middle childhood influence children's ability to adapt and succeed over time?
 - c. For multilingual learners, what aspects of a learning domain afford greater access or pose greater challenges? What aspects can be vehicles for language learning? What aspects may provide a foothold into the learning domain?
 - d. How do classroom environments and informal learning environments contribute to adaptive skill learning, respectively and in concert?

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