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ASSESSMENT

WORKING GROUP

03

THE INTERNATIONAL SCIENCE AND
EVIDENCE BASED EDUCATION ASSESSMENT

Education
2030 4

REIMAGINING EDUCATION: THE INTERNATIONAL SCIENCE AND EVIDENCE BASED EDUCATION ASSESSMENT

THE INTERNATIONAL SCIENCE AND EVIDENCE BASED EDUCATION (ISEE) ASSESSMENT: WHY IS IT NECESSARY?

Education matters for people at all stages of life. But what is the purpose of education? This quintessential question must be asked before we can assess if our education systems are delivering on their promise. Should the goal of education be to develop human flourishing, or should it be to meet the demands of 'homo economicus'?

The way the future evolves very much depends on education. Today's mindsets on how we live, the economic and political systems we adopt, the formal and informal rules and regulations – the governance – that societies adopt, the way we perceive environmental and social problems are all very much influenced by the type (or lack) of education provided by past and present generations. The speed at which the world is changing, especially driven by technological progress and in transitioning from an industrial to a knowledge society, suggests that education can never be static and that the discourse on education, as **Dewey in 1923** asserted, 'should never come to an end'. It should be continuously evolving in response to the needs of society and the planet.

Therefore, now is the time to take stock and look ahead. A starting point is to ask two fundamental questions.

1. Are education systems serving the right purpose?

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2. Are they equipped to address the pressing challenges we face today?

To answer these questions, a systematic assessment of the existing knowledge on education and learning is urgently needed. An assessment grounded in science[1] and evidence drawn from a multitude of disciplines, encompassing the entire complexity of learning and education, should consider the following:

- the goals of current education systems and their relevance to today's societal needs;

- the broad socio-political contexts in which education is embedded; and

- the state of the art for learning processes drawing from the sciences of learning.

While other reviews and reports have addressed pieces of this complex education ecosystem, a transdisciplinary approach drawing on science and evidence is urgently needed to understand the multifaceted complex education systems across the globe. The International Science and Evidence based Education (ISEE) Assessment is the first to use an integrated conceptual framework that requires the separate streams of knowledge to be integrated to answer the two overarching questions above.

Science and evidence are now widely accepted as a necessary condition for most policy-making. The success of the Intergovernmental Panel on Climate Change (IPCC) in influencing policy by bringing the best science and evidence to the table has been instrumental in shaping climate change policy. However, the road has not been smooth, with many

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[1] We define science as the pursuit and application of knowledge and understanding of the natural and social world following a systematic methodology based on evidence (The Science Council, https://sciencecouncil.org/about-science/our-definition-of-science/).

critics questioning the validity of the science and the evidence provided. The same can be said of the Millennium Ecosystem Assessment, which brought to the fore the power of multidisciplinary science and evidence in informing policy-making for the sustainable use of biodiversity and ecosystem services for the well-being of humanity.

The field of education is no different. However, unlike in the environmental field, no previous attempts have been made to undertake an integrated transdisciplinary international assessment of science and evidence in the field of education. Education policy has been widely influenced by anecdotal information and is seldom backed up by transdisciplinary consensus science and evidence. However, our knowledge of learning processes and their bidirectional relationship with their contexts is rapidly increasing due to advancements in all disciplines addressing educational issues, and particularly over the past two decades by research from the field

of mind, brain and education. But the exchange of knowledge and information across the various disciplines working on education is challenging, as is the translation of new findings from this transdisciplinary research into educational policy.

Recognizing the need for, but absence of, a transdisciplinary approach to education and the limited use of science and evidence in education policy-making further strengthens the need for the ISEE Assessment. The term 'assessment' here refers to a critical evaluation of the state of existing knowledge on education and learning by a team of independent experts drawn from a broad range of relevant disciplines and from across the world. The knowledge base is peer-reviewed scientific literature, but also includes credible grey literature. The Assessment report consists of 25 chapters, which have undergone a blind peer-review process. It assesses findings from across disciplines through deliberative discussions amongst the team of diverse

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experts throughout the project. The accompanying Summary for Decision-Makers (SDM) addresses overarching key questions and translates the answers into policy-relevant recommendations. In addition, the Assessment highlights gaps in knowledge and suggests potential future research agendas. To be clear, the ISEE Assessment is of a very different nature from international large-scale student assessments, such as the Programme for International Student Assessment (PISA). Assessments like the one we present here have proved extremely fruitful in other domains (e.g. IPCC) to synthesize information available from a wide range of disciplines. This has never before been performed for education.

THE ISEE ASSESSMENT CONCEPTUAL FRAMEWORK AND STRUCTURE

The ISEE Assessment launched in September 2019 with an

expert meeting hosted by the Chief Scientist's Office, Quebec, Montreal and included approximately 20 scientists from around the world. Expertise was drawn from a range of education-related disciplines, such as international comparative education, human developmental and education psychology, neuroscience, cognitive science, economy and philosophy. This group gathered over three days to deliberate if an assessment of education would be beneficial, what it could contribute to education and what should be the conceptual framework. Although there were many disagreements among the experts, two common findings emerged: the need for an assessment of this nature; and the need for a transdisciplinary, multicultural and multiperspective lens to rethink the education agenda for the twenty-first century.

Developing a conceptual framework is an essential first step when undertaking an assessment of this nature. The

1 Beyond the SDGs: Towards Human Flourishing

- Basic material for a good life
- Constitutive Value of Knowledge
- Physical and Mental Health
- Freedom of choice, thought, and action
- Sense of meaning
- Social Justice and Equity
- Security and Peace (Global Citizenship)
- Familial, social and ecological relationships

2 Meditating Factors: Societal & Environmental Context

- Nature
- Demographics: Diversity
- Economy
- Socio-political: Culture and Values
- Science and Technology

Age (When)

4 Learning to

Know	Do	Be	Live together

Learning Experience

The Learning Experience

What	How	Where
• **Cognitive** (Knowledge) • **Socio-Emotional** (Empathy, Compassion, Mindfulness) • **Behavioural** (Action, Communication, Attitutes)	• Imitation • Play • Statistical • Social • Multisensory • Introspective	• Formal • Informal • Non-Formal

3 Education-Specific Policies & Practices

Student
- Selection and placement
- Assessments

Teacher
- Training
- Recruitment
- Remuneration
- Placement
- Curriculum
- Pedagogy

System Dynamics
- Technology
- Finance & infrastructure
- Governance, Ownership and Accountability
- Accessibility

Intervention

Figure 1. The ISEE Assessment Conceptual Framework of lifelong learning

ISEE Assessment Conceptual Framework (CF) aims to capture the key interlinkages between critical components of the education and learning system as understood by the education community represented by the group of experts convened at the first expert workshop. The CF presented above provides the basis for understanding and unpacking the complexity of the knowledge on education and learning across the world.

WORKING GROUP 1: EDUCATION AND HUMAN FLOURISHING

Working Group 1 on human flourishing unpacks **Box 1** and explores the interdependency between **Boxes 1 and 4** in the CF. **Chapter 1** provides an overview of the working group and the rationale for the chapters presented in the volume. **Chapter 1** also evaluates the concept of human flourishing and explores whether a definition can be

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used in education systems that allows context-sensitivity but still offers a common set of parameters. A main finding is that any education system for the future must acknowledge that volatility, uncertainty, complexity and ambiguity are central characteristics of our world, and education systems must rise to meet these challenges. **Chapter 2** reports that since the Second World War, educational policy and, in particular, education's role in human development has advanced along two parallel tracks with the dominant pathway focusing on the economy, while the other track, which takes a broader humanistic view emphasizing non-economic and non-instrumental objectives for human flourishing, is relegated. **Chapter 3** presents recent advances in cognitive and affective science that demonstrate the skills associated with flourishing can be cultivated through education, in the same way as literacy and numeracy. The chapter also outlines that about 82 per cent of teachers in teacher surveys consider there is a

disproportionate focus on exams in education in contrast to the well-being of students. A similar observation emerged with 73 per cent of parents preferring to send their children to a school where they would be happy even if their exam results were not as good as those achieved in high-stress exam oriented schools. Most students (81 per cent) indicated they wanted to learn more about how to look after their mental well-being.

Chapter 4 presents some perspectives and suggestions on curriculum, assessment and teaching reforms towards an education for flourishing following six curricular domains and six learning trajectories: learning to know and think, learning to do and evaluate, learning to learn, learning to live together, learning to live with nature and learning to be and become. This chapter recommends a slight adaptation of UNESCO's four pillars of education by introducing two additional pillars to equip education systems to better address today's societal and environmental

challenges. Chapter 5 completes the work of this working group by providing recommendations for strengthening schools towards an education for flourishing based on an assessment of existing school practices and environments.

WORKING GROUP 2: EDUCATION AND CONTEXT

Working Group 2 on contexts aims to understand how our social, economic and political systems influence, and are influenced by, our education systems **(the interdependent link between Box 2 and Box 3 in the CF)**. Furthermore, it examines how these contextual factors relate to diverse conceptions of the purpose of education **(the interdependent link between Box 1 and Box 2)**. The first four chapters look at the macro level: the social, political, economic and environmental contextual factors the group considers as having a critical influence in the design of education systems across the globe. The group looked at the political economy of education, as well as how global social phenomena such as colonialism and more recently climate change and sustainability issues have influenced education systems. These chapters look at how equitable education systems have been over the past fifty years and develop interesting insights into how meritocracy – frequently touted today as the great equalizer – actually threatens the equity and sustainability of education systems, fuelling acute competitive intensity and narrowing the experience of learning for millions. The concept of 'hereditary meritocracy' is shown to be a rising trend among Ivy League educational institutions in the United States, where the majority of the students are from the top 1 per cent of the income distribution while a minority come from households in the bottom 60 per cent. In addition, the chapter informs how socio-economic disparities affect the learning of the over 1 billion children who are impacted by poverty.

Chapter 2 on environmental contexts highlights the limitations

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of approaches to 'education for sustainable development', given that education remains wedded to a fundamentally human capital oriented vision looking at nature purely from an instrumentalist view rather than as an existential and intrinsic element of human flourishing. An important dimension in today's education systems is the notion of conflict and its implications for education. **Chapter 5** reports that the psychological impact of conflict (and related, trauma and poverty) on learning is huge and that, as far as possible, education systems must recognize and accommodate these impacts when designing curriculum, assessments and teacher training. Approximately 37 per cent of primary school aged refugee children are out of school, while only 24 per cent have access to secondary education and a dismal 3 per cent to higher education. Both **Chapters 5 and 8** (on curriculum) stress the role that education can and often does play in causing conflict, through fostering intolerance, xenophobia and societal division.

Chapters 6 and 7 of Working Group 2 then address the nature and extent of recent advances in neuroscience and technology as these relate to education, assessing how developments in these fields have both influenced, and have been influenced by, contextual factors (political, commercial, cultural, etc.). The final set of three chapters assesses how contexts have shaped, and are shaped by, key institutional features of our education systems that include curriculum and pedagogy **(Chapter 8)**, assessment **(Chapter 9)** and the teaching profession **(Chapter 10)**. These chapters elaborate how curriculum, assessment and teacher training are influenced by the political, social and economic climate in which education systems are embedded. Taken as a whole, the analysis presented in **Working Group 2**, while underlining the crucial importance of education in today's world, also reminds us of education's darker aspects (e.g. its potential to fuel conflict, as well as ameliorate it) and of its limitations as a resource for solving the world's problems if the contextual factors are

not aligned towards peace and sustainability. A key conclusion is the need to balance hope in education's transformative potential with awareness that fully realizing its capacity to promote human flourishing requires far-reaching changes in our political and socio-economic order.

WORKING GROUP 3: EDUCATION AND THE LEARNING EXPERIENCE

Working Group 3 on the learning experience assesses the relationship between the 'what', 'how', 'where' and 'when' of learning, and how they relate to UNESCO's pillars of education, in light of state-of-the-art evidence from the science of learning, and studies of the socio-economic, environmental and other challenges we face today **(the interdependent links between Box 4 with Boxes 3 and 1 in the CF)**. Building on the definition of education and learning as a 'relational' process **(Working Group 1)** and insights from brain imaging studies, the role of social and emotional learning (SEL) is incorporated into all four aspects of learning.   **Chapter 4** on social and

emotional foundations of learning highlights that the learning experience at the individual level is intrinsically cognitive, emotional and social, as there is no clear dissociation between cognitive and emotional functions of the brain; rather learning occurs from the interconnectedness of neural networks across many functions. The chapter reports that although SEL improves learning outcomes by 7 to 11 per cent, it only constitutes about 7 and 4 per cent of learning in primary and secondary education respectively.

Chapter 2 on brain development and maturation highlights the non-linear nature of brain development and learning as a result of a lifelong dynamic and mutually interacting interplay between nature and nurture, contrary to the long-held belief in the competing forces between biology and culture. Although the themes of individual differences and learning differences overlap to some extent, experts from **Working Group 3** strongly felt that separate chapters on individual differences and learning differences and

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disabilities were needed. Therefore, **Chapter 3** provides new evidence demonstrating that individual differences in human development and learning arise from reciprocal interactions between biological, psychological and sociological factors. It calls for an integrated multidisciplinary approach to the study of human development, and its conceptualization in education. **Chapter 4** provides details of SEL, what it entails and offers to the learning experience. The chapter underscores the high returns to investment in SEL and its contribution to not only academic achievement but also to social issues such as bullying, substance abuse, aggression, and depression, among others. **Chapter 5** emphasizes the importance of building a strong foundation of academic skills, such as literacy and numeracy, to scaffold other skills and develop flourishing. This underscores the importance of the integration of SEL with the more traditional competencies of literacy and numeracy within education systems to reach for human flourishing, which we call the 'whole-brain approach'.

The chapter also emphasizes the importance of mother tongue instruction in the first formative years before second languages are introduced to achieve the best possible learning outcomes while highlighting the findings of the **2016 UNESCO Global Monitoring Report** that about 40 per cent of the global population does not have access to instruction in the language they understand.

Chapter 6 raises important questions relating to inclusive education versus special needs education and presents findings suggesting that care should be taken when designing inclusive education policies. Emphasizing that one in every five to ten children expresses some form of learning difference such as dyslexia or dyscalculia, it highlights that particular attention should be given to disabilities that are invisible but significantly affect learning. About 40 per cent of countries do not collect data on prevalence, school attendance and school completion for students with disabilities/differences, limiting informed and effective

policy-making to close gaps in access and learning under the inclusive education umbrella. The call for universal, preventive screening emerges as a clear policy recommendation, while also recognizing that careful implementation is essential. **Chapter 7** addresses 'where we learn' and explores how built spaces, natural spaces and digital spaces affect learning. It looks at the roles of these different kinds of spaces for learning, attainment, interpersonal relationships, skills development, well-being and behaviours across UNESCO's four pillars of education. The chapter also explores how learning spaces can be actively shaped, felt and understood through practices and policies that occur within and around them.

WORKING GROUP 4: EDUCATION - DATA AND EVIDENCE

The ISEE Assessment was initiated with the idea of using science and evidence as its founding pillars. However, we soon noticed that the terms evidence and data prompted a slew of questions and clarifications that we did not anticipate. Recognizing the diversity of views and perspectives of what a science and evidence based assessment means, a small group of experts was commissioned to provide more clarity and guidance on what evidence means and how data can and should be used in education practice and policy-making. This working group's focus is on seeking the best way to provide answers to the questions: what worked?; what is working best generally?; and will a given intervention work here and now? A new taxonomy of eight tiers or levels of evidence guides matching available evidence to these questions and assess the strength of this evidence. The experts in this group provide a deeper understanding of how effect size and consistency of effect sizes influence learning outcomes, and how they can – and cannot – be used in practice and policy guidance. They also illustrate the potential of this modern approach to evidence based education by discussing the EEF (Education

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Endowment Fund) Evidence Database, effectively providing a proof of concept regarding some of the key ideas put forward as the new norm.

Working Group 4, in particular **Chapter 3**, highlights the importance of understanding and interpreting uncertainty. The concepts of p-values and statistical significance, together with confidence intervals, are explained and recommended as the new standard practice to be used when presenting empirical evidence in support of practice and policy-making. The core finding from **Working Group 4** is that science and evidence based education practice and decision-making are evolving into a more complex set of questions, but are potentially very fruitful undertakings, for which it is key to understand the limitations of extant data and evidence in striving to create, obtain and use recent evidence. A clear and transparent discourse surrounding the assumptions and caveats in the analysis should always be provided so that practitioners and decision-makers are aware of limitations and uncertainties.

GOVERNANCE AND SOCIAL PROCESS OF THE ISEE ASSESSMENT

The ISEE Assessment is a first of its kind for the field of education. Most studies reviewing education and learning primarily take a single disciplinary lens with very little collaboration, especially across traditional educational study disciplines and the newer science of learning disciplines. A key component for a successful endeavour of this nature is mutual respect and acceptance of multiple perspectives and a culture of 'agree to disagree'. In addition, an open culture is needed in which experts keep an open mind, truly listen to others and are fearless in asking questions to ensure transparency in assumptions and terminology. Finally, there must be a process in place to facilitate consensus building across all experts in order to create a synthesis of findings to be used by policy-

makers. Achieving the above will strengthen education systems and facilitate learning for the benefit of the individual and society.

An Advisory Board guided by two co-chairs was formed, comprising eminent persons from academia, business and policy, to provide support and guidance to the Assessment. The primary function was to ensure the relevance and credibility of the Assessment exercise. The overall scientific work of the Assessment was guided by the two Assessment co-chairs, one from the social sciences and the other from the natural sciences. The primary responsibility of the Assessment co-chairs was to ensure smooth collaboration across the various disciplines within and across working groups and to ensure the strictest scientific rigour was applied to the Assessment exercise. The co-chairs also were responsible for synthesizing the Assessment findings in the SDM document and a shorter headliners document that conveys the key messages and policy recommendations from the ISEE Assessment.

Each working group had two senior co-chairs supported by a junior co-chair, always combining experts from traditional educational studies and the sciences of learning community. Recruitment for these positions was a non-trivial process. Many early invitations were politely rejected because the work was outside those individuals' comfort zones, as well as requiring them to find common ground and come to shared consensual conclusions with experts and scientists outside their own communities and bubbles. This in itself was an important finding as a new social contract for education is designed and implemented by member countries in response to UNESCO's Futures of Education report released in November 2021.

Once the group leaders were identified, the arduous process of identifying the authors and structure of the chapters for the various working groups took place. The tendency to identify familiar faces and colleagues was only natural and therefore stringent requirements for each chapter

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to ideally have at the minimum two disciplines represented were established, alongside the strong recommendation to reach a representative author team in terms of geographic location and gender. However, the process was not always perfect and sometimes a chapter has leaned further towards a particular discipline or perspective than we ideally would have liked.

In order to minimize disciplinary bias but also to ensure scientific credibility, a blind peer-review process was put in place. Review editors, again from different disciplines, were identified to oversee the review process to ensure legitimacy, credibility and the optimal selection of the most appropriate reviewers for each of the chapters across all four working groups. The secretariat overseeing the logistics of the assessment was responsible for compiling the review comments and supporting the review editors to ensure all comments were adequately addressed by the respective chapter authors before they were approved for publication.

THE OUTPUTS

The results of the ISEE Assessment are presented in four volumes, each presenting the findings from each of the four working groups. As mentioned earlier, three working groups present state-of-the-art knowledge on education and learning based on the CF developed for the ISEE Assessment, and one on the meaning and use of data and evidence. Needless to say, there are many interlinkages across these working groups and attempts have been made to insert cross-references where necessary.

The SDM is an essential output from the ISEE Assessment. The SDM is presented not as a summary of each working group, but as a synthesis across all the working groups. The SDM is structured along five key questions of relevance for policy-makers. This involved 'harvesting' the answers to each question from all four volumes and presenting them in an integrated fashion that reflects the complexity and

interconnectedness among the various components within the education sector. The SDM presents the overarching key messages, findings and recommendations that emerge from the full ISEE Assessment report.

A headliners document forms part of the overall package, providing a brief overview and reflecting the key take-home messages and policy recommendations. It is meant to offer a snapshot of the ISEE Assessment and is a quick reference primarily for decision-makers and policy-makers.

CONCLUDING REMARKS

The ISEE Assessment is a first for the education sector. It brings together a critical mass of experts and scientists working in the field of education. The process of bringing together over 300 experts and scientists from a range of disciplines has been a challenging task but offers an

exciting learning experience of transdisciplinary collaboration within education. The two-and-a-half year journey produced new insights but, more importantly, provides the basis for future such assessments. The assessment process and the findings suggest that transdisciplinary research and collaboration is a necessary condition for any education policy-making, especially at the global level. The insights emerging when a range of disciplines combine their relevant research and perspectives are invaluable, offering understandings that sometimes contradict conventional intuitions. It is also important to emphasize the process of consensus building among experts coming from multiple disciplines on findings which might be controversial or uncertain.

This first assessment highlights the richness of evidence and data on learning and education systems, but it also demonstrates how fragmented and compartmentalized these are across the world. Another key observation from the Assessment

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is that many of the experts and scientists were uncomfortable assigning confidence levels to the findings and the subsequent recommendations. This will need attention if we are to ground the science of learning into education policy-making. An international science organization representing multiple disciplines with a mandate on education should ideally carry out an assessment like the ISEE Assessment periodically in the future.

In 2021 UNESCO called for a new social contract in 'Reimagining Our Futures together: A New Social Contract for Education'. We are optimistic that the take-home messages, key findings and policy recommendations put forward by the ISEE Assessment will

guide countries across the globe when designing the blueprint for this new social contract. An education for human flourishing using a whole-brain, learner-centric approach acknowledges the interconnectedness between cognitive, social and emotional dimensions, and how these are influenced heavily by societal and contextual factors. Furthermore, recognizing and understanding the vast individual differences in development and learning is key when designing any social contract on education in any part of the world.

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03

EDUCATION *& the Learning Experience*

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03

EDUCATION &
the Learning Experience

Working Group 3 assesses how education and skills acquisition for all learners at different stages of their life is affected by their learning experiences in and out of the classroom space, due to the uniqueness of each learner.

CHAPTER

1
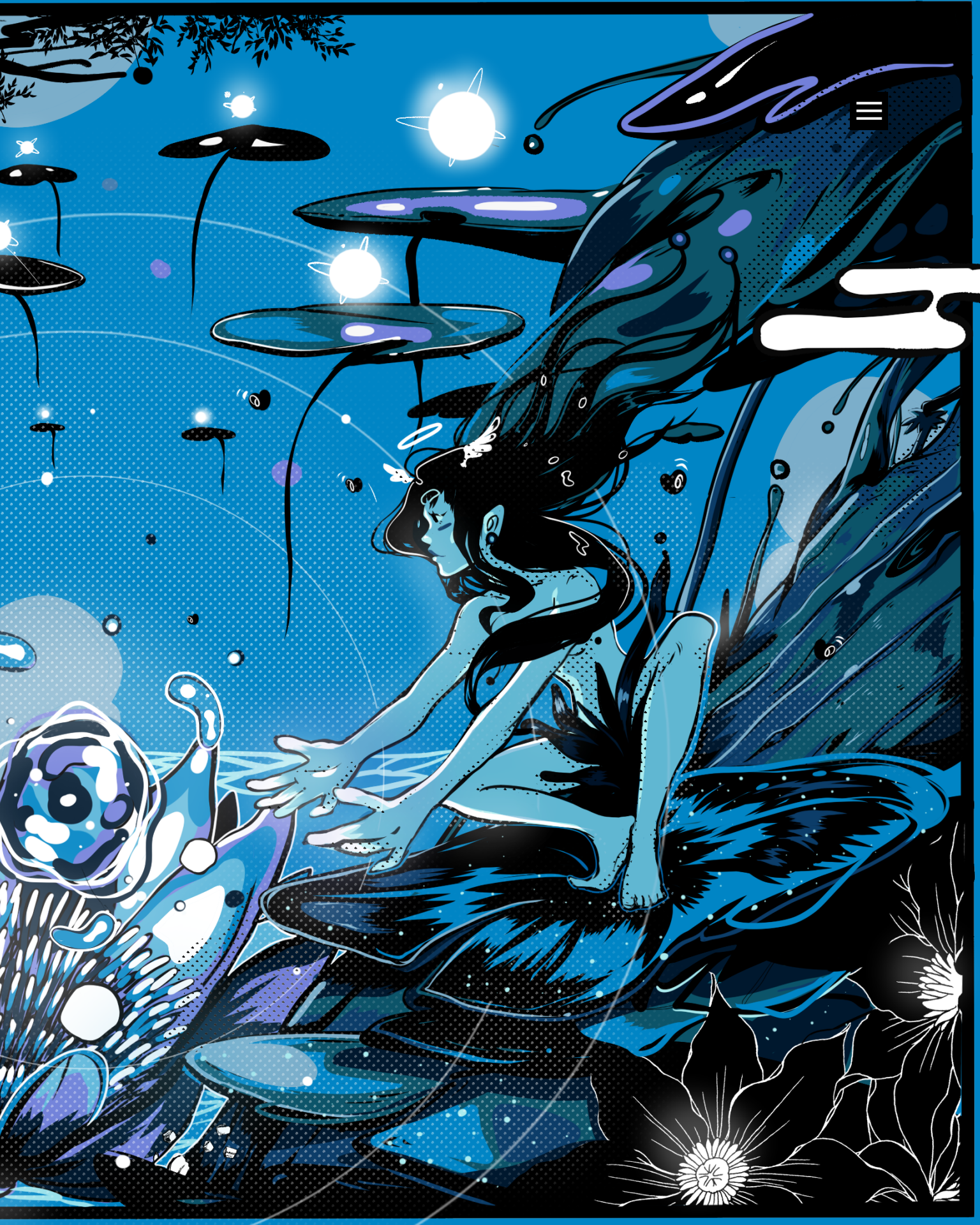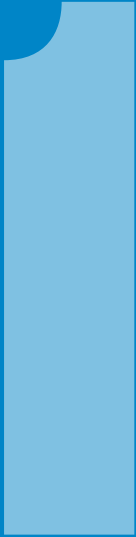
Towards an integrative view of the learning experience in the context of human flourishing

This chapter should be cited as:

This chapter introduces Working Group 3 of the International Science and Evidence based Education Assessment, which discusses the learning experience and provides some answers to the two fundamental questions addressed in this report: Are our education systems still serving the right purpose? And, are they equipped to address the pressing challenges we face? Based on the six learning trajectories defined in Working Group 1 (i.e., learning to know and think, learning to do and evaluate, learning to learn, learning to live together, learning to live with nature and learning to be and become), this section takes a transdisciplinary approach to determine the genetic, neurobiological, psychological, social and environmental factors that underpin the learning experiences of diverse learners, and their complex interactions. We start the chapter by defining the key concepts that are the foundation of the six chapters in this section. We then present briefly the most influential models of development and learning before providing a brief overview of the chapters in this section.

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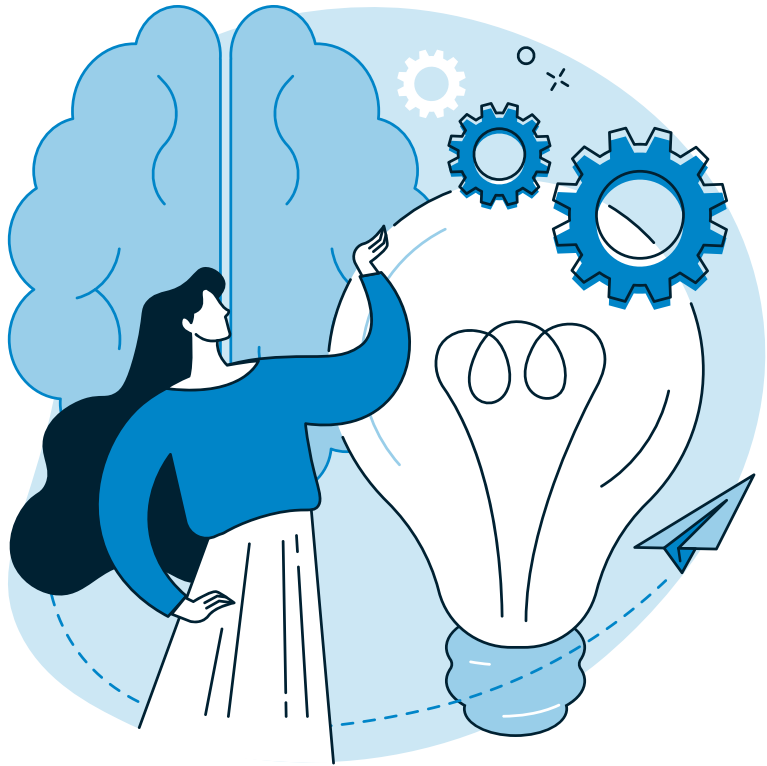
1.1

Introduction: central concepts, definitions and debates

Working Group 3 (WG3) explores the learning experience by assessing research covering the many interrelated influences on individual learners' experiences. The learning experience arises through complex interactions between intersecting factors including genes, brain development, language, cognitive abilities, social emotional skills, environment and culture. In this chapter, we define central concepts and describe an integrative approach to learning experience. Note that the contextualization of learning and education is addressed in depth in **WG2**. Throughout the six chapters of **WG3**, we take a transdisciplinary approach and integrate evidence from the biological, psychological

The learning experience arises through complex interactions between intersecting factors including genes, brain development, language, cognitive abilities, social emotional skills, environment and culture.

and social sciences **(Youdell et al., 2020)**. We acknowledge that human development is dynamic and individual differences in learning experiences arise from complex interactions between biological, psychological and socio-political factors. We also recognize the shortcomings of the assessment because most of the psychological science and educational research evidence reviewed by **WG3** is drawn from studies on populations of the Global North, which represents a minority of the world's population **(e.g. Henrich, Heine and Norenzayan, 2010; Nielsen et al., 2017)**. This suggests an urgent need to promote and support more inclusive and large-scale studies across countries from the Global North and Global South to understand better how the learning experience is modulated by a number of sociocultural, political and environmental factors across countries **(Brown, Mistry and Yip, 2019)**.

Learning experience is defined by the International Bureau of Education **(UNESCO-IBE, 2013, p.36)**.

A wide variety of experiences across different contexts and settings which transform the perceptions of the learner, facilitate conceptual understanding, yield emotional qualities, and nurture the acquisition of knowledge, skills and attitudes. In educational settings learning experiences are ideally challenging, interesting, rich, engaging, meaningful, and appropriate to learner needs. Previous learning experiences are considered to be key factors predicting further learning.

Adopting a transdisciplinary approach to learning and the learning experience has been, in part, dictated by the polysemic nature of the term across disciplines, but also by the emphasis that each discipline has on how, what, when and where we learn. For example, in neuroscience, the focus is on how learning occurs, through the formation of new neural circuits and other structural and functional changes in the brain. In contrast, in education research focused on curriculum

Another key factor at the root of the learning experience is the emotions engaged in the learning process and, more specifically, the social interactions and emotions supporting or impeding learning.

and assessment, the focus is on what is learned and what learning outcomes should be achieved through education **(WG2-ch8, ch9)**. As evident in **WG3-ch7**, other fields, such as environmental sciences, geography and/or architecture, address questions about the various ways of where we learn and how it affects our learning experience. Across the seven chapters in **WG3**, the when we learn question is also addressed by reviewing evidence for sensitive periods of brain development during early childhood and adolescence **(WG3-ch2)** and for age-related change in cognitive and socio-emotional abilities supporting learning **(WG3-ch3, ch4, ch5)**.

Another key factor at the root of the learning experience is the emotions engaged in the learning process and, more specifically, the social interactions and emotions supporting or impeding learning. In the context of learning and education, social emotions relate to teachers and classmates, such as compassion, admiration, contempt, envy, anger or social

anxiety in the classroom and social and emotional learning (SEL) as 'the learner's experiences of contexts and emotions related to learning and embedded in learning' **(WG3-ch4)**. Thus, the learning experience at the individual level is intrinsically cognitive, emotional and social. Moreover, recent research in neuroscience investigating the connectivity across brain networks has revealed that there is no clear distinction between cognition and emotion. Thus, learning is heavily influenced by cognitive, emotional, motivational and social brain processes that are all interdependent, as well as by culture (e.g. value and belief systems and practices shared by groups) and other environmental factors (e.g. socio-economic status/ SES) **(WG3-ch2, ch6)**.

Defining learning and the learning experience for human flourishing, as we aim to do in **WG3**, leads inevitably to the debate regarding whether 'nature' (genes) or 'nurture' (environment) has a greater influence on human development. It is well established

> **Human brain development is a continuous, non-linear process that begins during the first weeks of gestation and lasts until early adulthood.**

that human cognition and behaviours arise through complex interplay between nature and nurture **(see Mitchell and Frith, 2019 for a concise review)**. Human brain development is a continuous, non-linear process that begins during the first weeks of gestation and lasts until early adulthood **(e.g. Karmiloff-Smith, 2009)**. Findings from multiple disciplines highlight that development is dynamic, with bidirectional interactions between biological features (e.g. DNA, brain structure) and environmental factors (e.g. economic forces, cultural influences, relationships). Yet, much research is still influenced by the framework of biology and culture as competing forces, and the epistemological divide between the disciplines interested by the factors at play in the learning experience and their inability to 'join forces' stems in part from the weight they give to the role of 'nature' or 'nurture' in human development. We argue that this false dichotomy between focusing on the variables at the level of the individual (as in psychology and cognitive science) versus the variables at the level of institutions (as in educational and sociological research) can distract researchers and policy-makers from studying how the two interact. For example, developmental psychology researchers have often assumed that individual differences in cognitive skills influence differences in academic outcomes, but have only recently begun to investigate how education in turn shapes cognitive development **(e.g. Morrison et al., 2019; Peng and Kievit, 2020)**. Academic and cognitive skills gained in a variety of contexts have direct reciprocal interactions with each other over the course of education and development, and these interactions facilitate mutual growth. Taken together, these new lines of evidence demonstrate that human development and learning arise from reciprocal interactions between biological, psychological and sociological factors and call for an integrated multidisciplinary approach to studying human development as in the present report.
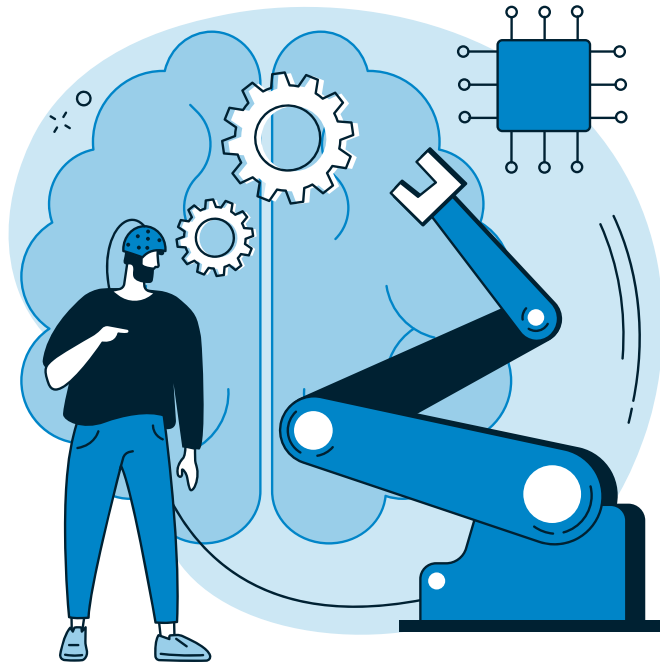
1.2 [Developmental theories: how and when we learn]{.underline}

Questioning the learning experience in and out of schools requires a clear understanding of the psychological mechanisms at play in human development. Jean Piaget is considered one of the founders of modern developmental psychology and proposed one of the most influential models of cognitive development **(Piaget, 1947, 1983)**. In his seminal constructivist theory, Piaget argues that children progressively acquire a logical understanding of the principles that govern the physical world by directly acting in it. According to this theory, the logical structures of children's minds become increasingly more complex throughout four fundamental shifts (or stages) during which the logical structures at a given stage are combined to create more complex structures at the next stage. These shifts occur at about the same age for all children in all cultures. Piaget's constructivist theory has been widely criticized because it (a) underestimates the rich conceptual knowledge of infants on the mathematical and physical principles of their environment and social

> The socio-cultural-historical theory of human development emphasizes that learning and development cannot be dissociated from the context in which they occur.

and emotional principles of the agents acting in their environment **(Spelke, 2000)**, and (b) overestimation of the logical abilities of adolescents and adults **(Kahneman, 2011)**. While Piaget's theory essentially addressed the cognitive nature of the learning experience, others, such as Lev Vygotsky, stressed the interactions of social, cultural, historical and individual factors in human development. The socio-cultural-historical theory of human development emphasizes that learning and development cannot be dissociated from the context in which they occur **(Schunk, 2012)**.

While these two theories, along with others, still have a major impact on education, research has since provided evidence that human development is more complex than initially thought. There is a growing consensus that human development should not be viewed as an incremental stage-like process, but as a complex, non-linear and dynamic process characterized by a great variability of learning trajectories across individuals, and where

learning and development in one domain supports the learning and development in others, in an interactive mutualistic system **(Van der Maas et al., 2006)**. The most recent models, such as the interactive specialization framework proposed by Johnson **(2001, 2005, 2011)**, conceptualize human development in the context of brain maturation. According to this model, the functional characteristic of a given cortical region is determined, among other things, by its connectivity to other cortical regions, as well as by their activity. In this context, the emergence of new abilities with age is associated with changes in networks of brain regions, and not just changes within one or a few specific regions.

In conclusion, human development is rooted in the interactive specialization of multiple brain networks, a biological process that is highly influenced by the cultural, economic, social, cognitive and emotional environment in which humans live.

1.3

Learning experience through the six learning trajectories

The chapters in **WG3** explore the learning experience across the six learning trajectories introduced and refined in **WG1-ch4**: learning to know and think, learning to do and evaluate, learning to learn, learning to live together, learning to live with nature and learning to be and become. These learning trajectories are reflected in individual's development through various chapters as follows.

Brain development and maturation in the context of learning (**WG3-ch2**) discusses the educational implications of research on mechanisms underlying brain development

and learning. It focuses on brain functioning, how the brain develops with age and how it affects the development of learning abilities, the neural processes involved in cognitive development and learning, and the factors that impact knowledge acquisition and executive functioning also with regards to sex differences and similarities. The chapter argues that human brain development is a complex, dynamic, continuous and non-linear process and provides examples of how biological processes and social factors have mutual effects on the brain's development and therefore on learning. These processes can inform education on how learning

works and the various modalities through which an individual learns and thinks and how the ways we learn to know and think can be affected and constrained by the brain function and structure.

Individual differences and influences on learning **(WG3-ch3)**

covers the biological, psychological, environmental and social factors that contribute to individual differences in learning. The chapter discusses the bi-directional interactions of intrinsic biological features and external environmental factors and argues that individual differences emerge from the interaction of a wide range of molecular, psychological and environmental factors (social, economic and cultural) that shape individual differences and influence learning. The interplay of these factors creates various capacities and differences that enable individuals to regulate their learning and confront challenges differently, which is particularly reflected in meta-cognitive skills and motivational factors impacting learning to learn competencies.

The social and emotional foundations of learning **(WG3-ch4)**

features analysis of the significance of SEL in educational practices. It emphasizes the nature of learning, which is inherently social, relational and affective, and how social and emotional experiences interact with learning processes. The chapter describes the development of social and emotional skills across the lifespan with regards to neurobiological, social and cultural factors. It also argues that social, cultural, temporal and physical contexts affect the experience of SEL and developing socio-emotional skills. These contextual factors affect the experience of SEL in, for example, relationships and interactions with peers, family, community and the environment. Learning to live together and learning to live with nature result from the ability to communicate with others, understand each other, respect others and from aspects of human-to-human communication, as well as relationship with nature, which includes the connections and interrelations between living beings and the natural world

Literacy and numeracy are key gateways to academic learning and both culturally dependent skills requiring learning invented symbol systems.

that are central to understanding the world in which we live. This is particularly important in indigenous contexts, where the relations between individuals and the environment play a significant role in how to live with nature. Life satisfaction and well-being are also associated with socio-emotional skills and competencies that individuals develop through a trajectory of learning to be and become in which they learn how to take care of themselves, how to live wisely amidst change and to become guided by an informed sense of purpose and meaning in life.

Foundations of academic knowledge **(WG3-ch5)** assesses the acquisition of academic knowledge and skills in domains including literacy, numeracy, sciences, arts and physical education. It examines how learning trajectories arise from complex interactions between individual brain development and sociocultural environments. The chapter argues that the course of child development involves interactions among neurobiological, cognitive, socio-emotional, cultural and

environmental influences. Literacy and numeracy are key gateways to academic learning and both culturally dependent skills requiring learning invented symbol systems. The fundamental skills that are described and discussed in this chapter are the bases for the development of academic knowledge and the trajectory of learning to know and think, which concerns the pursuit of knowledge and the various modalities of thinking that reflect the different forms of knowledge spanning from knowledge of culture, science, arts, environment and human rights, to knowledge of self and other. Learning to do and evaluate denotes a trajectory of skills such as literacy, numeracy, arts and sciences.

Identifying and supporting children with learning disabilities **(WG3-ch6)** assesses the ways to identify and support children with learning disabilities by describing considerations for children's learning needs. Learning disabilities arise through a dynamic interplay of biological and environmental

> **... more work is needed to understand better the impact of different pedagogical practices on students' learning trajectories in various cultural contexts.**

factors and therefore are seldom attributable to one specific cause. Recognizing the need to provide inclusive education to support all learners, the chapter asserts that more work is needed to understand better the impact of different pedagogical practices on students' learning trajectories in various cultural contexts. In this respect, the chapter contends that not only early identification of learning disabilities is important to ensure children have access to the support they need, but also a more inclusive education approach to help all learners reach their full potential. This inclusive pedagogy could promote a trajectory of learning to live together supporting children with learning disabilities.

Learning spaces: built, natural and digital considerations for learning and learners **(WG3-ch7)** explores the influence of different learning spaces and places – built spaces, natural spaces and digital spaces – on the learning experience. It looks at the role of these different kinds of spaces for learning, attainment, interpersonal relationships, skills development,

well-being and behaviours across the six trajectories of learning. The chapter discusses the growing recognition that where education takes place matters for what is learned and what is afforded or assumed through various learning environments. It also recognizes the need for a broader uptake of non-formal, informal and non-school based learning for furthering socio-emotional and behavioural learning outcomes, as well as increasing cognitive learning outcomes for diversity of learners. This includes the consideration of technological affordance in the configurations of learning environments, as well as non-built and natural spaces – sustainable school design and place based learning – that can increase the sense of meaning and connection with nature and the development of social awareness and sensitivity to contemporary ecological issues, such as sustainability, global warming and climate change (learning to live with nature).

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CHAPTER

2

Brain development and maturation in the context of learning

This chapter should be cited as:

The goal of this chapter is to present and discuss the educational implications of basic and applied research on the mechanisms underlying brain development and learning. This chapter first provides the basic principles of neuroscience for education, with a focus on the general principles of brain function and organization, standard brain imaging methods to investigate the learning and the developing brain, the neural processes involved in cognitive development and learning, and sex differences and similarities in the brain and cognition. It then details with concrete examples how biological processes – including sleep, exercise, nutrition, trauma, poverty, deprivation, threat and academic stress – can influence the brain and learning. The chapter concludes by outlining misconceptions about neuroscience, or 'neuromyths', and the importance for education of debunking them.

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2.1

Why neuroscience is relevant to education

The brain is crucial for learning. Neuroscience, in addition to psychology, can inform education because understanding underlying neural mechanisms can further improve our understanding of how learning works and how learning is constrained by brain function and structure **(Thomas, Ansari and Knowland, 2019)**. In addition, the brain, like every biological organ, requires some specific conditions (e.g. nutrition, stress levels, exercise, sleep, air, social interactions and cultural environment) **(Thomas, Ansari and Knowland, 2019)** to be healthy and thus it is relevant for learning to identify these conditions.

Educators are often informed of brain based learning techniques **(Simons et al., 2016)**, but many of these techniques are only commercial programmes that have no actual scientific evidence **(WG2-ch7)**. Therefore, it is important that educators and policy-makers are aware of the basic principles of neuroscience and the potential of false promises.

2.2

Brain, development and learning

2.2 .1

BASICS IN NEUROSCIENCE

2.2 .1 .1

Brain imaging enables non-invasive investigations of the human brain at rest or during cognitive tasks … and has provided deep insights into human brain functioning.

GENERAL PRINCIPLES OF BRAIN FUNCTION AND ORGANIZATION

Understanding of brain functioning has benefited from the development of several domains within neuroscience: cognitive brain imaging, computational neuroscience, integrative/multiscale neuroscience and cultural neuroscience **(WG2-ch7)**. Brain imaging enables non-invasive investigations of the human brain at rest or during cognitive tasks (see details on brain imaging techniques below) and has provided deep insights into human brain functioning **(Toga, 2015)**. In particular, functional brain imaging has established two fundamental principles of neurophysiological organization: segregation and integration, namely the segregated or modular deployment of functional specialization within interconnected brain regions **(Friston, 2009)**. Brain imaging has also contributed to the development of the concept of neural plasticity (see below), which refers to the anatomical and/or functional changes underlying cognitive and behavioural

... there is no clear distinction between cognition and emotion: learning is heavily influenced by cognitive, emotional, motivational and social brain processes that are interdependent.

changes throughout life or in response to an intervention, for example, learning or training **(Rosen and Savoy, 2012; WG1-ch3; WG3-ch3, WG3-ch5, WG3-ch6).** Computational neuroscience, which uses mathematical tools and theories to study the brain, has leveraged behavioural and physiological evidence that neurons (the nerve cells in the brain) represent knowledge in the form of probability distributions and acquire new knowledge by following the rules of probabilistic inference **(Pouget et al., 2013)**. Such probabilistic predictions shape how we perceive and comprehend the world **(Teufel and Fletcher, 2020)**: the brain continually generates models of the world to predict the most plausible explanation for what is happening in each moment. The recent development of multiscale neuroscience, integrating the different levels of description, from neurons to behaviour, aims at putting the different pieces of the puzzle together to provide a global picture of brain functioning **(van den Heuvel, Scholtens and Kahn,2019)**.

Hence, at all levels of organization, connectivity is a central element of nervous system architecture and function: neurons with dendritic and axonal connections form the microscale fabric of brain circuitry,[1] and macroscale brain regions and white matter fibre tracts (bundles of long axons) form the infrastructure for system-level communication among brain regions and information integration **(Betzel and Bassett, 2017)**.

Different functions are associated with different brain regions, but researchers are increasingly realizing that most complex functions such as learning or memory rely on networks of interconnected – rather than individual – brain regions. In particular, the large amount of information coming from the environment (e.g. listening to someone talking to us) is integrated through multimodal associative regions that are connected to different unimodal networks. Additionally, many cognitive functions are intertwined and rely on similar underlying

[1]Dendrites are projections from neurons that receive information and axons are projections from neurons that send information.

> ...the brain can be regarded as a statistical organ that employs hierarchical (i.e. deep) generative models to accumulate sensory evidence.

circuitry **(WG1-ch3, WG2-ch7; WG3-ch4, ch6)**. What is also becoming increasingly clear is that there is no clear distinction between cognition and emotion: learning is heavily influenced by cognitive, emotional, motivational and social brain processes that are interdependent **(WG3-ch4, WG3-ch5)**.

Finally, cultural neuroscience studies have reported that culture (e.g. value and belief systems and practices shared by groups) underwrite the functional brain architectures that enable inference and learning **(Han and Northoff, 2008; Han, 2013; Chiao et al., 2015; WG2-ch7, WG3-ch3, ch5)**. Throughout the life course, culture affects brain maturation **(Li, 2003; Goh et al., 2007; Chiao, 2018)**. Observed cultural influences on brain activity during development reflect the effect of culture on structural and functional brain changes during development. Culture also modulates the effect of the environment on brain and behavioural changes related to learning. For instance, culture modulates social and emotional processing **(Harada et al., 2020)**.

In summary, the brain can be regarded as a statistical organ that employs hierarchical (i.e. deep) generative models to accumulate sensory evidence. This accumulation or assimilation has separable timescales: (1) inference, mediated by neuronal dynamics and synaptic activity – to infer states of the world in the moment; (2) attention, mediated by neuromodulation of synaptic efficacy – to select salient sensory signals for inference; (3) statistical learning, mediated by experience-dependent synaptic plasticity – to encode contingencies and statistical regularities generating sensory signals; (4) structure learning (optimizing the structure of generative models), mediated by neurodevelopment and synapse selection (pruning) – to optimize the structure of the brain's generative model; and (5) encultured learning, mediated by culture and evolutionary psychology – to ensure environmental contingencies are learnable **(Friston, 2010)**.

2.2 .2

BASICS OF BRAIN BIOLOGY

The brain consists of different types of cells that communicate with each other. Neurons consist of a cell body, an axon and one or more dendrites. Axons are used to transmit information to other cells using an electrical signal called an action potential. The axon subdivides into different branches which connect to other cells at synapses. The electric action potential may trigger the synaptic release of different 'neurotransmitters' (chemical substances such as serotonin or dopamine) or be directly transmitted from neuron to neuron electrically through gap junctions. Thus, neurons communicate through both electrical and chemical signals. Neurons receive input from many other neurons, on average 7,000 synaptic connections per neuron.

Glial cells, such as astrocytes and oligodendrocytes, which regulate homeostasis in the brain, provide support and protect the nervous system, aid in recovery from brain damage such as a stroke, and modulate activity within synapses by regulating neurotransmitter, oxygen and ion uptake. For example, oligodendrocytes aid in faster transmission along axons by creating an insulating myelin sheath, consisting mostly of fat, and wrapping that around axons. This fatty layer makes the parts of the brain with many axonal connections look white, which is why those parts are referred to as white matter. Grey matter, on the other hand, contains mostly neuronal cell bodies and glial cells.

Grey matter makes up the folded outer layer of the brain, also called the cortex. The cortex is usually subdivided into different lobes: the frontal lobe, the parietal lobe, the temporal lobe and the occipital lobe. Deeper in the brain, under the cortex, lie subcortical brain structures such as the amygdala and hypothalamus. The hippocampus has a kind of

> **Cognitive activity is associated with several processes at the cellular level.**

transitional architecture, not quite cortical or subcortical, that is referred to as the allocortex.

2.2 .3

HOW BRAIN IMAGING METHODS INVESTIGATE THE NEURAL BASIS OF COGNITION

Cognitive activity is associated with several processes at the cellular level. Different techniques are available to measure brain activity, and each technique focuses on a specific cellular process. Briefly and very schematically, for any cognitive task, from perception to higher-level functions, the brain generates electromagnetic waves that reflect the electrical activity of neurons. This electrical activity propagates along axons and modulates the release of neurotransmitters from the sending (or presynaptic) neuron, which then bind to their receptors on the receiving

(or postsynaptic) neuron. This chemical activity, which can be measured with positron emission tomography (PET), also produces an electromagnetic field. This electromagnetic field can be measured with electroencephalography (EEG) or magnetoencephalography (MEG). EEG and MEG have high temporal resolution (around 10 ms) but their spatial resolution is limited, especially for EEG, which is roughly 20 centimetres[3]. For cortical structures, MEG has comparable spatial resolution to magnetic resonance imaging (MRI) (i.e. around 1 millimetre), but MEG's spatial resolution for deeper structures is more limited. The activity of neurons requires energy and induces metabolic activity with a local increase in the intake and consumption of glucose and oxygen by neurons. This metabolic activity can be measured with PET. When neurons are more active, the cerebral blood flow to their region increases because neurons need more glucose and oxygen when they are more active; when they are less active, blood flow to them
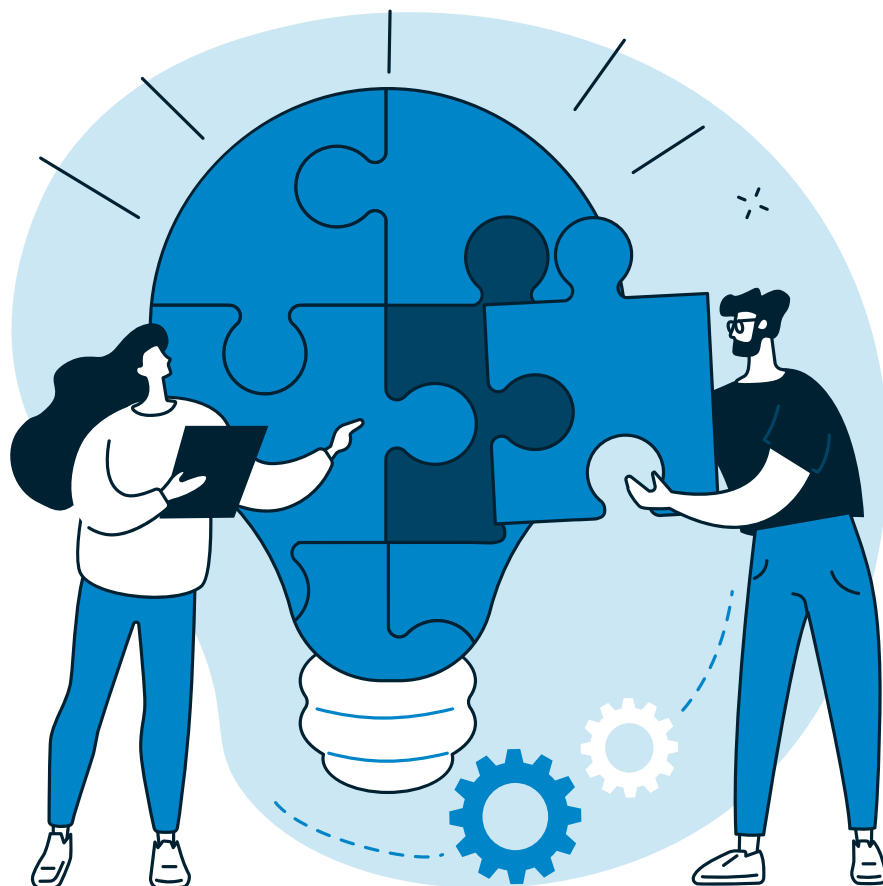
decreases. This hemodynamic activity can be measured with functional magnetic resonance imaging (fMRI), functional near-infrared spectroscopy (fNIRS) and PET. Of note, contrary to other 'non-invasive' imaging techniques, PET has limited use to study brain function in healthy participants, especially children, because it uses radioactive substances, or radiotracers, to measure changes in metabolic and hemodynamic processes. It also has less precise spatial resolution than fMRI (roughly 5–10 millimetres3). fNIRS is far cheaper and more portable than fMRI and has better temporal resolution (though not quite as good as EEG or MEG), but it has worse spatial resolution than fMRI (though better than EEG), much shallower penetration depth into the brain, and does

fMRI has emerged as a key approach to studying the neural bases of learning, as it can detect activation in the whole brain during sensorimotor, perception and high-level cognitive processes ...

not allow for the collection of structural images of brain anatomy (which MRI provides).

fMRI has emerged as a key approach to studying the neural bases of learning, as it can detect activation in the whole brain during sensorimotor, perception and high-level cognitive processes as long as there is not too much movement **(Ogawa et al., 1992)**. However, the relatively poor spatiotemporal resolution (typically millimeters and seconds) and the indirect nature of the imaging markers to reflect neural activity remain important limitations of fMRI and fNIRS which can be partly overcome by combining different methods (e.g. EEG or MEG). Functional connectivity between brain areas is usually estimated from functional data by calculating the relationship (e.g. correlation) between regional time series. Functional connectivity maps can be obtained either in the context of task-related brain activity or in 'resting' conditions through resting-state functional acquisition **(Greicius et al., 2003)**.

For anatomical – as opposed to functional – connectivity the preferred method is diffusion-weighted MR imaging **(dMRI; Basser, Matiello and Le Bihan, 1994; Le Bihan, 2003)**, which can produce stunning tridimensional maps of the orientation in space of white matter tracts and brain connections, as well as provide information on white matter and grey matter microstructure and integrity. dMRI has revealed faulty brain connections linked to diverse conditions, including dyslexia, dyscalculia and anxiety disorders **(Siugzdaite et al., 2020)**.

Another relatively recent imaging technique is magnetic resonance spectroscopy (MRS), which is a non-invasive method for measuring biochemical changes in the brain. While MRI can detect the anatomical location of something in the brain (such as a tumor), MRS can detect the chemical composition of that tissue, for example, comparing the chemical composition of normal brain tissue with abnormal tumor tissue.

2.3 How the brain develops with age

Human brain development is a complex and dynamic process that begins during the first weeks of gestation (embryonic period) and lasts until early adulthood. The availability of non-invasive three-dimensional MRI methodologies has changed the paradigm and allows investigation of the living human brain structure. Because of its relative safety, MRI is well adapted for studying individuals at multiple time points and longitudinally following changes in brain structure and function that underlie the early stages of cognitive development. Before the advent of brain imaging tools, structural brain changes were inferred from post mortem data. However, there were major concerns about their generalizability due to the questionable good health of the studied individuals who had died very young.

MRI is well adapted for studying individuals at multiple time points and longitudinally following changes in brain structure and function that underlie the early stages of cognitive development.

On the other hand, despite the advantages of in vivo MRI described above, MRI cannot measure structural changes at the cellular or molecular level, and the physiological interpretation of an MRI signal is not straightforward or univocal. In addition, MRI data acquired at the early stage of brain development (before birth) are very noisy due to acquisition constraints (e.g. movement artefacts, short acquisition duration) and difficult to analyse due to low spatial resolution and age-dependent tissue contrast and structure size. Comparing anatomical brain measures derived from MRI across ages after birth is more reliable. The spatial and temporal patterns of developmental changes observed in recent MRI studies reflect patterns that were observed postmortem fetal tissue, demonstrating the validity and compatibility of these methods **(Dehaene-Lambertz and Spelke, 2015; Dubois and Dehaene-Lambertz, 2015; Dubois, Kostovicand Judaš, 2015; Dubois et al., 2014).**

2.3 .1

FOETAL BRAIN DEVELOPMENT

Most of the cellular and molecular events underlying brain formation and development begin before birth. During prenatal development and after birth, neurons are 'born' (neurogenesis) and new synapses are made (synaptogenesis). Neuronal proliferation (increase in the number of neurons) and migration; cytoarchitectonic aggregation of specific neuronal populations are both completed before birth. On the other hand, the specification of morphological and molecular neuronal phenotypes (growth of dendrites, dendritic spines and axons, continues throughout life); as does establishment of neuronal circuitry and connectivity (growth of axon pathways and synapse creation, i.e. synaptogenesis); proliferation and differentiation of glial cell types;

Paralleling changes at the microscopic level, early brain development is characterized by dramatic changes in cortex morphology due to the cortical folding process that begins at ten GW.

and myelination **(Kostovic and Judaš, 2015)**. Almost all neurons in the human brain are born prenatally.

There are distinct developmental phases **(Kostovic, Sedmak and Judaš, 2019)**. By the end of the early foetal period (ten to sixteen gestational weeks,[2] GW), all embryonic brain divisions and cell proliferation are visible. During the mid-foetal period (seventeen to twenty-five GW), the subplate contains numerous synapses and represents a transitory substrate for axonal ingrowth and outgrowth. This is the basis of the early foetal circuitry, with the spontaneous generation of functional activity. The hippocampal formation develops while limbic pathways are partly already developed. The first long associative corticocortical pathways start to grow.

During the late foetal to early preterm period (twenty-six to thirty GW), while the intensity of neuronal proliferation decreases, migration continues. This period is characterized by ingrowth

of axons, synaptogenesis and dendritic differentiation of neurons. Afferent connections from subcortical structures are relocated from the subplate into the cortical plate, leading to the onset of sensory-expectant cortical functioning that co-exists with endogenous activity. Efferent pathways from the cortex (e.g. to the spinal cord, striatum, thalamus, pons) then show accelerated development, which promotes motor activity in particular. The growing long pathways are then particularly vulnerable to hypoxic-ischemic damage.

The late preterm period (thirty-one to thirty-six GW) is characterized by changes in brain architecture (neuron size, density, laminar thickness and spatial arrangement); dendritic differentiation and synaptogenesis in the cortical plate; intense growth of long associative corticocortical pathways; and proliferation of glial cells (astrocytes, oligodendrocytes). The functional status becomes elaborated and immature cortical

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[2]Gestation weeks are equal to post conceptional weeks plus two weeks of amenorrhea.

> ... subtle variations in the in utero environment, as indexed by birth weight, are accompanied by differences in post natal cognitive abilities.

responses are elicited by sensory inputs.

Paralleling changes at the microscopic level, early brain development is characterized by dramatic changes in cortex morphology due to the cortical folding process that begins at ten GW **(Kostovic, Sedmak and Judaš, 2019)**. The beginnings of gyrification (the birth of gyri, the 'mountains' of the cortex) and the sulcation (the birth of sulci, the 'valleys' of the cortical relief) become manifest after twenty-four GW and greatly heighten during the last weeks before birth. The heritability of the cortical folding is estimated between 0.2 and 0.5 **(Le Guen et al., 2018)**, meaning that early prenatal or perinatal environmental factors like alcohol exposure **(De Guio et al., 2014)**, intrauterine growth restriction or twin pregnancy **(Dubois et al., 2008)** and birth weight **(Kersbergen et al., 2016)** determine 50 per cent to 80 per cent of the cortical folding process.

LONG-TERM EFFECTS OF FETAL BRAIN DEVELOPMENT

Several studies have reported that subtle variations in the in utero environment, as indexed by birth weight, are accompanied by differences in postnatal cognitive abilities **(Raznahan et al., 2012; Walhovd et al., 2012; Shenkin, Starr and Deary, 2004; also see WG3-ch3 on individual differences in brain and learning)**). It also seems that the event of birth and the gestational age at birth, even when the birth is not premature, have a major impact on later brain growth as seen in ten-year-old children **(El Marroun et al., 2020)**. In addition to a global proxy measure of 'uterine optimality', analysis of sulcal morphology can provide information on the prenatal constraints imposed by the structure of some specific brain regions on later cognitive development and learning **(Cachia et al., 2016)**. Several studies in

> Different environmental backgrounds, such as bilingualism (after birth) or twin pregnancy (before birth), can modulate the relationships between sulcal patterns and cognitive abilities.

typically developing participants report a long-term relationship between cortical sulcation at birth and cognition several years and decades later in several cognitive domains critical for learning, such as cognitive control **(Fornito et al., 2004; Borst et al., 2014; Cachia et al., 2014; Tissier et al., 2018)** and reading **(Borst et al., 2016; Cachia et al., 2018)**. Different environmental backgrounds, such as bilingualism (after birth) **(Cachia et al., 2017; Del Maschio et al., 2018)** or twin pregnancy (before birth) **(Amiez, Wilson and Procyk, 2018)**, can modulate the relationships between sulcal patterns and cognitive abilities.

Learning and memory processes in relation to the in utero environment are already beginning to develop in foetuses, as highlighted by early observations of newborns. At birth they show preferences for specific tastes related to the mother's diet during pregnancy (e.g. anise) **(Schaal et al., 2000)** and for the mother's voice **(DeCasper and Fifer, 1980)**. Their behavioural reactions and brain activity to speech-like auditory

sounds differ depending on whether the sounds are familiar or not from when the fetus was in the womb, and greater prenatal speech exposure has been found to be related to enhanced brain activity, with generalization to other types of similar speech sounds **(Partanen et al., 2013)**. Familiar odours and speech rhythms, learned pre- or postnatally, have calming effects during a painful procedure **(Rattaz, Goubet and Bullinger,2005)** or during sleep **(Lang, Del Giudice and Schabus, 2020)**. This suggests an important role of memory processes in the newborn's development during the pre- and perinatal period.

2.3 .3

INFANT BRAIN DEVELOPMENT

Birth represents a huge stress for the baby, which shows very high concentrations of stress-related hormones after normal vaginal delivery **(Lagercrantz, 2016)**, but this seems important for its

> **As infants become more specialized in the language(s) in their environment, their ability to hear sounds unique to other languages gradually recedes.**

adaptation to the extra-uterine environment. At full-term birth, the proliferation and migration of neurons are complete, the limbic system is relatively mature and some major long projection, commissural and associative pathways have finished their growth, providing the basis for sensory-driven connectivity.

Newborns are able to recognize their mothers' faces **(Pascalis et al., 1995; Sai, 2004)** and voices **(DeCasper and Fifer, 1980)** and show an early preference for their native language **(Moon, Cooper and Fifer, 1993; Nazzi, Bertoncini and Mehler, 1998)**. Their ability to discriminate between phonemes **(Kuhl, Tsao and Liu, 2003; Kuhl, 2004)** or faces **(Kelly et al., 2005)** evolves during the first post natal year, in relation to their environment and social interactions, and this allows them to specialize progressively in the stimuli that are relevant to them. During this process, infants perform statistical learning computations that are affected by experiences **(Saffran and Kirkham, 2018)**. During at least the first

six months of life, before this specialization has occurred, infants can discriminate the sounds in all languages **(Eimas et al., 1971; Streeter, 1976)**. As infants become more specialized in the language(s) in their environment, their ability to hear sounds unique to other languages gradually recedes.

Human brain development, compared to that of other species, has one of the slowest rates of development and takes many years to reach maturity **(Thompson and Nelson, 2011)**. The newborn period is characterized by dendritic differentiation, an explosive phase of synaptogenesis, cell death and axon selection (pruning), intense growth of short corticocortical fibres, proliferation of astrocytes and oligodendrocytes, myelination, and the development of tertiary sulci that make the newborn brain resemble the adult brain **(Kostovic, Sedmak and Judaš, 2019)**. This allows the newborn to enter a new phase of emotional and social interactions with complex multimodal sensory stimulation.

… during brain development, both generative and degenerative processes take place.

During the first post natal year, brain volume increases massively. During early infancy (one to three months of age), synaptogenesis and dendritic differentiation increase rapidly, while other processes develop more smoothly **(Kostovic, Sedmak and Judaš, 2019)**. The growth of axonal pathways slows down, except for intracortical axons that grow until up to six months of age. Mid-infancy (nine to twelve months of age) is characterized by synaptogenesis in both primary and associative cortical regions, relative maturity of pyramidal neurons, disappearance of the subplate remnant, gradual delineation of cortical areas and the beginning of myelination of the cortical pathways **(Kostovic, Sedmak and Judaš, 2019)**. This underlies the development of cognitive functions in interaction with the social environment and the first appearance of advanced cognitive abilities associated with the prefrontal cortex (PFC) **(Diamond, 1990, 1991; Fiske and Holmboe, 2019; Fiske et al., 2021)**.

During the second post natal year, although the number of synapses has reached a temporary plateau, associative areas still show immature cytoarchitecture. Cortical connectivity pathways tend towards adult patterns despite still incomplete myelination, and high-level cognitive, executive, social and emotional functions are still immature.

In summary, during brain development, both generative and degenerative processes take place. During prenatal development and after birth, neurons are 'born' (neurogenesis) and new synapses are made (synaptogenesis). Perhaps surprisingly, degenerative processes such as apoptosis (cell death) and synaptic pruning (elimination of unused or extra synapses) are also crucial for child development. This process is thought to aid in making information processing more efficient by eliminating unnecessary connections and improving the ratio of signal to noise.

Compared to other structures in the brain, the frontal cortex in particular develops more slowly, and keeps developing until around age twenty-three.

2.3 .4

CHILDHOOD BRAIN DEVELOPMENT

It is important to note that although some influential classic psychological theories often describe child development in terms of accumulative (distinct stages) and linear development, brain research is more supportive of continuous non linear development **(see also WG1-ch4, WG3-ch4 for childhood development)**.

As children develop, white matter connections between brain regions show a steady increase with age **(Giedd, 2004)**. For grey matter, the pattern is a bit different. After birth there are initial increases in grey matter, after which pruning takes place. Importantly, this process does not occur at the same speed in each brain region. Compared to other structures in the brain, the frontal cortex in particular develops more slowly, and keeps developing until around age twenty-three **(Giedd, 2004)**.

The most anterior portion of the frontal cortex, the PFC, is linked to processes such as working memory, inhibition and cognitive flexibility (components of what are called 'executive functions' (EF) **(Diamond, 2013)** that are crucial for the learning process. Every teacher will know that young children find it much more difficult than older children and adults to stay focused on schoolwork and ignore irrelevant stimuli in the classroom. This can in part be explained by the late developing PFC.

Myelination of axonal fibres producing white matter tracts also plays a critical role from late pregnancy to early adulthood in the development of sensory, motor and associative networks, with high variations across regions regarding the age of onset and period length of myelination.

2.3 .5

ADOLESCENT BRAIN DEVELOPMENT

Sensitivities in adolescent brain development can help explain why adolescence seems such a critical turning point, which is highly relevant to education.

Although previously most attention on brain development was directed towards the early childhood years, adolescence is now also increasingly recognized as a sensitive period for brain development **(Casey, 2015; WG1-ch3, WG3-ch4)**. Adolescence is a key period in life during which development can spiral into positive or negative trajectories **(Crone and Dahl, 2012)**. Sensitivities in adolescent brain development can help explain why adolescence seems such a critical turning point, which is highly relevant to education. As mentioned earlier, brain regions involved in cognitive control, especially the PFC, are late-maturing regions with massive synaptic pruning at puberty **(Huttenlocher, 1979)**. While the PFC is still not completely developed, other brain regions appear to be relatively hyperactive. The brain's 'reward centre', specifically the ventral striatum and nucleus accumbens, shows more activity in mid to late adolescence than in younger children and adults **(Silverman, Jedd, and Luciana,**

2015). This has led researchers to hypothesize 'imbalance models' of brain development with a hyperactive reward system and an underdeveloped PFC, which is thought to result in an imbalance between cognitive and socio-emotional processes **(Ernst, Pine and Hardin, 2006; Steinberg 2008; Somerville and Casey, 2010)**. This theory has been used to explain negative adolescent behaviours such as risk-taking, and use of alcohol and other toxins. This view has now shifted to emphasize more positive aspects: adolescents have the capacity for complex cognitive functions, especially when strong socio-affective stimuli are not interfering **(Crone and Dahl, 2012; Casey, 2015; WG3-ch4)**. Increased striatum activity in adolescence has also been linked to positive behaviours, such as prosocial behaviour **(Spaans, Peters and Crone, 2020)**, better learning from feedback **(Davidow, 2016)** and better learning in a risky context **(McCormick and Telzer, 2017)**. This may provide interesting pathways to further investigate how to

2.4 Sex differences and similarities in the brain

The question of sex differences in brain structure and function, cognition and academic skills still raises debate in the current scientific literature.

Sex-related differences are apparent across multiple levels of analyses and start from the very early weeks of human prenatal life **(Thomason, 2020)**. For instance, sex differences are apparent in birthweight centile and in foetal and neonatal morbidity and mortality; there are also differential effects of the foetus' sex on the mother, differential susceptibility of male and female foetuses to pathological conditions in pregnancy and, moreover, male foetuses tend to be more vulnerable to detrimental effects from early adversity.

... sex differences in brain development likely evolve dynamically throughout life.

2.4 .1

SEX DIFFERENCES IN BRAIN STRUCTURE AND FUNCTIONING

Sex differences in neurodevelopment have been described for structure, organization and function **(Paus, 2010; Giedd, 2012; McCarthy, 2016)**. The current literature suggests the existence of sex differences in the anatomical development of grey and white matter a (such as brain volume, grey matter density, cortical thickness, cortical surface area and gyrification) **(Williams, 2021; WG3-ch6)**, as well as in anatomical and functional connectivity networks (in white matter tracts and in cerebral blood flow **(Kaczkurkin, Raznahan and Satterthwaite, 2019)**. Although a well-cited seminal study reported that, compared to girls, delayed brain development in boys is likely due to delayed puberty **(Lenroot, 2007)**, some later studies have failed to replicate these findings

(Aubert-Broche et al., 2013; Tamnes et al., 2013; Wierenga et al., 2019). These discrepancies may be related to the fact that sex differences in brain development likely evolve dynamically throughout life **(Kaczkurkin, Raznahan and Satterthwaite, 2019)**. Statistical issues, like the method used to correct for inter-individual differences in body size **(Williams, 2021)**, may also contribute to these discrepancies.

2.4 .2

SEX HORMONES AND THE BRAIN

The literature has also reported the effects of sex hormones on the brain in general **(Marrocco and McEwen, 2016; Choleris et al., 2018)**, and on PFC-related cognition and neuroplasticity more specifically **(Shansky, 2004; Hao et al., 2007; Evans, 2015)**. Sex hormones modulate many neural and cognitive functions due to their action at the whole-brain level **(McEwen and Alves, 1999)**. Sex differences

emerge in many brain regions throughout the life course due to both genetic and epigenetic factors (i.e. environment-dependent gene expression) **(McCarthy et al., 2009, McCarthy and Nugent, 2015)**. For instance, stress that interplays with learning **(Vogel and Schwabe, 2016)**, induces sex-specific effects on brain plasticity **(McEwen, Gray and Nasca, 2015)**, at cellular **(Shors, Falduto and Leuner, 2004; Shansky, 2009; Bowers, Waddell and McCarthy, 2010; Goldstein, 2010; Yagi, 2019)** and cognitive **(Shansky, 2004, 2006)** levels.

Because of the indirect and bi-directional relationship between cerebral activity and mental processes, there is a high risk of interpretation bias due to gender stereotypes when translating sex differences in the brain into psychological differences **(Fine et al., 2013; WG3-ch6)**. For instance, purely looking at global volume, boys have on average larger brains than girls, but this is unrelated to cognitive performance **(Wierenga et al., 2019)**.

==... induces sex-specific effects on brain plasticity, at cellular and cognitive levels.==

SEX DIFFERENCES IN COGNITION AND ACADEMIC SKILLS

The outcome of research on sex differences in cognitive abilities – such as language, spatial orientation and mathematics **(Nazareth, 2019; Peragine et al., 2020)** – and in emotional and rational processing is still under debate **(Schmitz and Höppner, 2014)**. Similarly, research on sex differences in academic skills has reported diverging results, despite a growing interest from researchers and policy-makers in recent decades **(Guez, Peyre and Ramus, 2020)**. Meta-analyses on achievement test scores tend to show that girls perform better than boys in language tests **(e.g. Hedges and Nowell, 1995; OECD, 2015)**, while boys perform better than girls in mathematics tests **(e.g. OECD, 2015; Reilly, Neumann and Andrews, 2015)**. But analyses of school exams and marks often report an

Data also show that each human brain consists of a mosaic of 'female', 'male' and 'mix' features.

advantage of girls in all subjects **(Guez, Peyre and Ramus, 2020)**. The stability and magnitude of these sex differences in academic skills are also highly debated, with some researchers arguing that they have been stable over the decades, while others claim that they are disappearing **(Stoet and Geary, 2020)**. Understanding the level of stability of these differences would provide valuable insight into another fundamental question, that is, the degree to which sex differences in cognitive abilities are related to environmental and genetic factors.

For note, several neurological disorders associated with learning difficulties such as dyslexia, attention deficit hyperactivity disorder and autism spectrum disorder are diagnosed much more frequently in boys than in girls. Conversely, major depressive disorder, anxiety, panic disorder and anorexia nervosa are much more often diagnosed in adult women than in adult men **(McCarthy et al., 2012; WG3-ch6)**.

2.4 **.4**

CONTESTED TOPICS

Recent literature has challenged the essentialist view of the human brain and its static sexual dimorphism implying highly dimorphic, internally consistent male and female nervous systems largely fixed by a sexually differentiated genetic blueprint **(Rippon et al., 2014; Kaczkurkin, Raznahan and Satterthwaite, 2019**

2.4 **.4** **.1**

INTER-INDIVIDUAL VARIABILITY

Even if inter-group differences (i.e. between males and females) are found when looking at specific anatomical and functional cerebral measures/variables, intra-group differences are often extremely large and the high degree of overlap between distributions of males and females argues against any conclusion at individual level (e.g., Ritchie et al.'s **(2018)** MRI study on 5,000 adults).

| 2.4 | .4 | .2 |

INTRA-INDIVIDUAL VARIABILITY

Data also show that each human brain consists of a mosaic of 'female', 'male' and 'mix' features. Hence, there is no uniformly 'female' or 'male' brain, since the relative proportion of these characteristics varies substantially between individuals, and possibly changes throughout life **(Joel et al., 2015)**.

| 2.4 | .4 | .3 |

INFLUENCE OF GENETIC AND ENVIRONMENT FACTORS

Since it is currently impossible in most anatomical, functional and behavioural studies to disentangle biological sex differences from those resulting from environmental and social influences throughout life **(Kaczkurkin, Raznahan and Satterthwaite, 2019)**, the sole influence of genetic factors

2

CHAPTER

==...the structural and functional organization of the nervous system continuously and dynamically adapts throughout life to environmental conditions and experiences.==

is difficult to assess. Studies investigating female/male differences in sex hormones and behaviour are often correlational, and analyses frequently consider hormonal levels as 'purely' biological and causally primary variables without considering the reciprocal influence between biological and environmental factors **(Rippon et al., 2014; WG3-ch6)**

2.4 | .4 | .4

BRAIN PLASTICITY

The current understanding of human development posits that the structural and functional organization of the nervous system continuously and dynamically adapts throughout

life to environmental conditions and experiences, and that the modulation of endocrine function by those factors contributes to its plasticity. Recent data from endocrinology, evolutionary behavioural science and developmental biology raise serious doubts about the popular understanding of female/ male behaviour as rooted in a biological core. Current models of those disciplines do not support the assumption that there is a unidirectional causality link from genes to behaviour via hormones and brain, nor that our behaviours are rooted in some reminiscence of mental processes of our paleolithic ancestors **(Fine et al., 2013; WG3-ch3, WG3-ch6).**

2.5

Brain plasticity and learning

Neuronal cells and their synapses undergo structural (morphological) and metabolic (biochemical) changes throughout development, as the brain grows, learns and ages in constant, dynamic and adaptive interaction with the external world. Altogether, brain plasticity comprises experience-dependent changes in the size, number and shape of synapses, cells and circuits.

Brain plasticity is present throughout life (for learning, following brain insult, etc.), but these processes are much more important during development, when networks are not yet fully 'stabilized'. This contributes to why learning is so efficient during childhood **(WG1-ch4)**.

2.5 .1

BRAIN PLASTICITY AT THE CELLULAR LEVEL

Neurons are formed quite early in the embryo, so that by the end of the first trimester of pregnancy the brain has most of the neurons that will survive into adulthood. Embryonic neurons are small and have few dendrites, in comparison with adult neurons. During development, neurons that are frequently activated by other neurons grow and become progressively more branched, while neurons that are seldom activated loose synapses and eventually are eliminated through a process of programmed cell

The acquisition and consolidation of memories depend on the formation of new synapses as well as on the strengthening and weakening of previously existing synapses.

death (apoptosis). This process selects the most adaptive neuronal pathways and curbs the excess of neurons formed in the embryo.

While most adult neurons are incapable of undergoing further cell division, neurogenesis persists until adolescence **(Sorrells eta al., 2021) and perhaps adulthood (Gould et al., 1999, Gage, 2002)** in the memory-related brain structure called the hippocampus. The acquisition and consolidation of memories depend on the formation of new synapses as well as on the strengthening and weakening of previously existing synapses.

At the functional level, the tagging of a synapse for subsequent remodelling **(Frey and Morris, 1997; Morris et al., 2003)** depends on neurophysiological phenomena called long-term potentiation (LTP) **(Bliss and Lomo, 1973; Bliss and Collingridge, 1993)** and long-term depression (LTD) **(Fujii et al., 1991; Dudek and Bear, 1992)**, which account respectively for the strengthening or weakening of a

postsynaptic electrical response. Depending on the frequency and intensity of the stimulation used for their induction, LTP and LTD may last for hours, days or even weeks **(Barnes, 1979)**. The link between memory processing and the occurrence of LTP and LTD has been extensively demonstrated **(Collingridge, 1985; Malinow et al., 1988; Izquierdo and Medina, 1995; Nicoll and Malenka, 1999, Kandel and Squire, 2000; Whitlock et al., 2006)**.

2.5 .2

BRAIN PLASTICITY AND MEMORY CONSOLIDATION

After being acquired, memories are stabilized through a series of specific processes termed memory consolidation. The first phase of memory consolidation, which comprises local changes at the synaptic level, coincides with LTP and lasts from several hours

to a few days. The second phase of memory consolidation, which comprises systemic changes at the level of multiple brain regions (e.g. hippocampus and neocortex), coincides with neurophysiological changes lasting from weeks to months to years.

While synaptic changes begin to occur during the waking experience that leads to learning, most of the changes required for memory consolidation take place during post-learning sleep. Slow-wave sleep promotes the bulk of sleep-dependent synaptogenesis **(Yang et al., 2014)**, and rapid-eye-movement (REM) sleep triggers most of the synaptic pruning as well as the strengthening of selected new synapses **(Li et al., 2017)**. During slow-wave sleep, the hippocampal-neocortical circuits activated during learning are reactivated; during REM sleep, consolidation of new learning into long-term memory occurs **(Cartwright, 2004)**.

When consolidated memories are retrieved they must be reactivated

at the electrophysiological level. The different elements of 'a memory' are stored in different areas of the brain and these different elements have to be reassembled when retrieving this memory. This mechanism is part of the reason why the memory can be inaccurate **(Lacy, 2013)**. As first shown by Karim Nader in the late 1990s, reactivated memories go from a latent hard-to-change form to a labile, easy-to-change form, which reopens the opportunity to strengthen, weaken or otherwise modify the memory contents, leading to the phenomenon known as memory reconsolidation. The biological scaffolding of this process corresponds nicely to one of its putative psychological corollaries, namely that the particular choice of study technique has major implications for learning.

Several students use boring, time-consuming and inefficient ways of studying **(Karpicke, Butler and Roediger, 2009)**. There is now plenty of evidence that students benefit more from active engagement with the material than passively

The different elements of 'a memory' are stored in different areas of the brain and these different elements have to be reassembled when retrieving this memory.

While repetition is positively correlated with short-term gains, variations in form and context are required to optimize long-term results, avoid habituation and promote integration of new and old knowledge.

receiving information **(Roediger and Karpicke, 2006; Freeman et al., 2014; WG2-ch8)**. In addition, active retrieval of previously learned material can lead to better long-term retention than passive restudy of the material **(Hogan and Kintsch, 1971; Whitten and Bjork, 1977)**. Retrieval practice comprises the resolution of problems, answering or formulating questions about the contents at stake, writing summaries about what was learned in one's own words, and holding peer-to-peer debates **(Agarwal et al., 2014; Agarwal et al., 2017)**. The benefits tend to be proportional to the difficulty level, and they can be obtained even when the students choose incorrect answers, as long as there is clear feedback **(Butler, Karpicke and Roediger, 2008)**. While repetition is positively correlated with short-term gains, variations in form and context are required to optimize long-term results, avoid habituation and promote integration of new and old knowledge **(Rosenbaum, Carlson and Gilmore, 2001; WG2-ch5)**. Students

should have the opportunity to practise content retrieval at least once for every content learned, since the most learning benefits come from the first retrieval practice attempt **(Rowland et al., 2015)**. When multiple retrieval practices are possible, they should be spaced rather than performed in a block **(Son, 2004; Cepeda et al., 2008)**.

The feeling of knowing is quite different from being able to remember specific information **(Yonelinas, 2002)**. Rather than actively retrieving contents, students tend to prefer the passive exposure to contents by rereading, which leads to a sense of familiarity that is often just an illusion of competence. While we tend to prefer things that are more familiar **(Montoya et al., 2017)**, 'remembering by recognition' is most often a failed strategy in the classroom. Retrieval practice is feasible in any school, does not involve much extra time and has a negligible cost **(Roediger et al.,**

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[3]Three quite useful guides on retrieval practice are provided by Henry L. Roediger III (http://psychnet.wustl.edu/memory/publications/), Jeffrey Karpicke (https://www.purdue.edu/hhs/psy/directory/faculty/Karpicke_Jeffrey.html) and Pooja K. Agarwal (www.retrievalpractice.org).

2.6

['Brain health': how biological processes influence the brain and learning](#)

SLEEP

Evidence accumulated over recent decades indicates that sleep is a key mediator of learning **(Stickgold and Walker 2005; Diekelmann and Born,** **2010)**, so it is quite worrisome for education that sleep is increasingly sacrificed for the sake of waking activities. The emergence of electro-electronic devices has been very deleterious for sleep **(Broman et al., 1996;Lima, Medeiros and Araujo, 2002; Peixot et al., 2009; Moreno et al., 2015)**, leading to a decrease in the quality and quantity of

Poor sleep is a risk factor for health disorders such as malnutrition, obesity, diabetes and hypertension, and correlates with academic deficits across a wide range of intellectual quotients.

sleep, which impacts negatively on approximately one third of the adult population in the United States (USA) **(Schoenborn, Adams and Peregoy, 2013)**. Poor sleep is a risk factor for health disorders such as malnutrition **(Beebe et al., 2013)**, obesity **(Jarrin, McGrath and Drake, 2013)**, diabetes and hypertension **(Spiegel et al., 1999)**, and correlates with academic deficits across a wide range of intellectual quotients (IQ) **(Erath et al., 2015)**. Sleep is an important mediator of socio-economic and health gradients **(Teixeira et al., 2004)**. For instance, the lack of consistent bedtime habits in USA preschoolers is associated with poverty and low maternal education **(Hale et al., 2009)**.

The mechanisms underlying sleep-dependent cognitive function involve brain oscillations and calcium-dependent molecular cascades associated with synaptic plasticity **(Stickgold and Walker, 2005; Diekelmann and Born, 2010; Mander et al., 2011; Ribeiro, 2012)**. Sustained waking leads to sleep deprivation, which impacts directly on these cascades impairing learning

(Vecsey et al., 2009). Insufficient sleep prevents new learning in the laboratory setting, that is, pre-training sleep is a necessary condition for the acquisition of new memories **(Yoo et al., 2007)**. Post-learning sleep has been shown to improve the learning and memory of declarative and procedural contents in the laboratory **(Plihal and Born, 1997; Stickgold and Walker, 2005; Ellenbogen et al., 2006)**. In recent years these experiments have been successfully extended to the school setting **(Kurdziel, Duclos and Spencer, 2013; Lemos, Weissheimer and Ribeiro, 2014; Cabral et al., 2018; Cousins et al., 2019)**, and may even double reading fluency in first graders **(Axelsson, Williams and Horst, 2016; Torres et al., 2020)**.

It is becoming increasingly clear that schools must offer children and adolescents the opportunity to sleep when needed, either to help the consolidation of newly acquired contents, or to compensate for prior sleep debt and restore the capacity to learn anew **(Ribeiro and Stickgold, 2014; Sigman et al., 2014; Axelsson, Williams**

and Horst, 2016). It is important to embrace naps in the school setting to unleash the full learning potential of students – and teachers as well.

2.6 .2

EXERCISE IN THE SCHOOL SETTING

The proliferation of electronic devices in recent decades has contributed to unprecedented pressure on physical activity (Hankonen et al., 2017). Insufficient or ineffective physical activity reaches the entire range of socio-economic classes, leading to increased body mass and severe health costs (Ng and Popkin, 2012; Fiuza-Luces et al., 2013). Despite recommendations and widespread health campaigns from the World Health Organization (WHO, 2011), and the Physical Activity Guidelines for Americans (U.S. Department of Health and Human Services 2018; Powell et al., 2019),

most children do not perform an adequate amount of physical activity to derive the full health benefits. In fact, fewer than 24 per cent of children ages six to seventeen years engage in the recommended sixty plus minutes of daily moderate-to-vigorous physical activity (National Physical Activity Plan Alliance, 2018). Among its many benefits, physical activity promotes improvement in several variables that impact brain and cognition, such as positive changes in brain structure and function and increases in brain derived neurotrophic factor (BDNF), a key protein involved in plastic changes in the brain related to learning and memory (US Department of Health and Human Services, 2018; Valkenborghs et al., 2019; Lubans et al., 2016). An adequate schedule of regular physical activity is necessary for the cognitive and brain health of children and adolescents (Vaynman and Gomez-Pinilla, 2006; Deslandes et al., 2009; Masley, Roetzheim and Gualtieri, 2009; Chaddock et al., 2011; Lubans et al., 2016; WG3-ch5). Exercise has an acute effect on cognition (Chang et al., 2012; Erickson et al.,

.. .schools must offer children and adolescents the opportunity to sleep when needed, either to help the consolidation of newly acquired contents, or to compensate for prior sleep debt and restore the capacity to learn anew.

2019; Pontifex et al., 2019), including EF **(Ludyga et al., 2016; Moreau, 2019; see also Drollette et al., 2014)** and attention **(Palmer, Miller and Robinson, 2013)**, which are important for enhancing learning and academic performance during the school day.

Several studies from neuroscience, psychology and educational science suggest that physical activity and aerobic fitness are beneficial for brain health and well-being **(Lubans et al., 2016; Erickson et al., 2019;Valkenborghs et al., 2019)**. Converging evidence indicates that at every age, people who are more physically active and have better aerobic fitness have better EF; furthermore, children who exercise more and are more physically fit tend to do better in school **(Hillman, Castelli and Buck, 2005; Voelcker-Rehage, Godde and Staudinger, 2010; Boucard et al., 2012; Scudder et al., 2014)**.

What is still debated are questions such as: how much physical activity is enough? Which type of exercise is best? When is the best time in the school day to engage in exercise to best support learning?

A difficult problem in this type of research is that much of the literature to date is correlational. In recent years some randomized controlled trials (RCT, the gold standard in intervention research) have indicated that causal relationships link physical activity, EF and memory **(Davis et al., 2011; Hillman et al., 2014; Mavilidi et al., 2020)**, while other studies failed to detect cognitive benefits related to physical activity **(see Álvarez-Bueno et al., 2017 and Vazou et al., 2016 for reviews)**. Regardless, fitter and more active children often score better on cognitive and scholastic tests, and in many cases neuroimaging tools are used to demonstrate brain regions and networks that support better behavioural performance. Alternative explanations also exist; thus it is also possible that these children, for example, have better self-control, which benefits both their ability to engage in regular physical exercise and their schoolwork.

Another important question is how physical activity might benefit cognitive and academic performance. Animal studies provide evidence for aerobic exercise leading to a cascade of molecular and cellular alterations, including increased growth factor levels, neurogenesis, angiogenesis (growth of blood vessels) and synaptogenesis, which encourages the production of new neurons and blood vessels as well as dendritic complexity and spine density **(Gomez-Pinilla and Hillman, 2013; Voss et al., 2013)**. In humans, benefits are observed in brain structure, including grey matter volume and white matter integrity; brain function including electrophysiological markers, cerebral blood volume and blood flow; and changes in neural network activation during cognitive task performance and while at rest **(Voss et al., 2013)**.

Therefore, it is crucial that schools provide ample opportunity for physical activity and structured exercise, in association with sleep, nutrition and training contexts **(Sigman et al., 2014; Ribeiro et al., 2017; Immordino-Yang, Darling-Hammond and Krone, 2019)**.

... it is crucial that schools provide ample opportunity for physical activity and structured exercise, in association with sleep, nutrition and training contexts.

2.7 Nutrition

The nutritional requirements of the human brain depend on the energy needs of several functional systems of the body. With 2 per cent of body mass, the brain consumes around 20 per cent of the body's energy. In particular, neural development is characterized by a complex pattern of nutritional requirements during the whole cycle of life. These requirements are complex and depend on the integration and interdependence of several organ systems involved in the digestion of food and absorption of nutrients into the blood, which are regulated by the brain in interaction with the gut and its microbiota and the modulation of the blood-brain barrier. Optimal brain development depends on a sufficient supply of different nutrients at specific times. While all nutrients are relevant to brain development, proteins, carbohydrates, polyunsaturated fats, iron, copper, zinc, iodine,

...since brain development is a lifelong process, adequate nutrition is critical from conception to late adulthood.

folates, and vitamins A, B6 and B12 have important influences beginning in the early stages of development. Potentially, their presence or absence during critical or sensitive periods can affect neural development. In a few cases it has been possible to identify periods during which the absence affects the neural organization of some function, as in the case of iron **(Lozoff, 2017)**. However, in many cases the existence of such periods and their possible effects are still being investigated. Although nutritional requirements are more critical during times of greater brain function organization, brain functions are not all organized at the same time: different neural networks are organized at different times during at least the first two decades of life. For example, by the second year of life glucose consumption in the brain – the main energy source for the brain – is equivalent to that of an adult. But this does not mean that the development of the brain is completed. Besides glucose there are other essential nutrients necessary for several important cellular functions, such as synapse

formation and elimination, that occur well beyond the first 1,000 days **(Goyal et al., 2014)**. Meanwhile, in the adult brain, glucose consumption for these and other related functions is approximately 10 per cent of the total metabolized by the brain; during childhood this rate could peak at 30 per cent. Thus, since brain development is a lifelong process, adequate nutrition is critical from conception to late adulthood.

2.8 Early experience, stress and trauma

2.8 .1

EARLY EXPERIENCE

From conception and throughout life, the nervous system is organized and modified based on the dynamic interaction between the individual and the world in which they live. The presence, lack or absence of material, sensory and social stimuli, and threats in developmental contexts, have been repeatedly associated with changes in different aspects of the structure and functioning of the nervous system during its development **(Lambert et al., 2016; Farah, 2017; WG2-ch5, WG3-ch4, WG3-ch6)**. Such changes, which occur due to the

adaptive nature of the components and connections of the nervous system, have been documented at different levels of organization, from the molecular to the structure and function of different neural networks for different kinds of deprivations and threats **(Sheridan and McLaughlin, 2014)**.

2.8	.2

STRESS

Various forms of deprivation and trauma lead to a stress response, which can take many forms and can influence learning in myriad ways. It prepares the body to respond quickly to perceived dangers, by raising heart rate and tensing muscles and preparing for 'fight or flight'. Exposure to moderate stress is important for learning how to handle stress, but severe and/or long-term (i.e. chronic) stress is associated with negative consequences. Severe or prolonged stress in early childhood can have an important impact on later development **(for e.g. Anda et**

al., 2006; Miller et al., 2009; Yam et al., 2015)**. Early stress can shape developing neural systems and changes how future stressful events are processed **(WG2-ch5, ch7)**.

Stress can be very present at school for both students and teachers: exams, deadlines, dysregulated student behaviour and interpersonal conflicts are just a few examples of the many events that may result in high levels of stress. Hormones and neurotransmitters released during and after a stressful event are major modulators of human learning and memory processes, with critical implications for educational contexts **(see WG2-ch5 for further discussion on neurobiological and neurohormonal responses to stress and their effect on cognition and emotion regulation; WG3-ch4)**. Stress markedly impairs memory retrieval, bearing, for instance, the risk of underachieving in exams **(Vogel and Schwabe, 2016)**. Recent evidence further indicates that stress may hamper the updating of memories in the light of new information, impair EF and induce a shift

Hormones and neurotransmitters released during and after a stressful event are major modulators of human learning and memory processes, with critical implications for educational contexts.

Working on social and emotional skills reduces stress by promoting students helping and supporting one another and increasing the sense of community in the classroom.

from a flexible, 'cognitive' form of learning towards rather rigid, 'habit'-like behaviour **(Schwabe et al., 2010; Schwabe and Wolf, 2013; Zareyan et al., 2020)**.

Stress in school can be reduced by consistency, knowing what to expect, and clarity about what is and what is not allowed. Working on EF and self-regulation reduces the stress from having dysregulated students in a class. Working on social and emotional skills reduces stress by promoting students helping and supporting one another and increasing the sense of community in the classroom. Exercise and yoga reduce stress **(Lane and Lovejoy, 2001; Williamson, Dewey and Steinberg, 2001; Gothe, Keswani and McAuley, 2016; WG1-ch3, WG3-ch4)**. The representation of stress is also important: students educated on the positive, adaptive benefits of stress arousal improve academic performance and evaluation anxiety in classroom exam situations is reduced **Jamieson et al., 2018, 2021)**.

2.8 .3

CHRONIC LIFE STRESS FROM CONDITIONS SUCH AS POVERTY

Exposure to stress and particularly exposure to chronic stress during gestation, infancy, childhood or adolescence has an impact on the brain, particularly on structures involved in cognition and mental health. Exposure to early stress is associated with alterations to the volume of the amygdala **(Tottenham and Sheridan, 2010; Gee at al., 2013; VanTieghem and Tottenham, 2018)**, and a trophy of the hippocampus **(Wei, Hao and Kaffman, 2014; Delpech et al., 2016; Dahmen et al., 2018)** and the PFC **(Cybele Raver, Blair and Willoughby, 2012; Hackman et al., 2015; Ursache et al., 2016; Haft and Hoeft, 2017)**. Stress alters dendritic growth and spine density as well as synaptic communication and circuits in brain regions that are maturing. These regions not only regulate the hypothalamic–pituitary–adrenocortical response

> ... short- and long-term effects of stress during development influence the course of brain development, the physiological response to stress and cause negative cognitive, emotional and behavioural responses both during development and throughout life.

to stress, but also control cognition, learning, EF abilities and emotional responses. Thus, short- and long-term effects of stress during development influence the course of brain development, the physiological response to stress and cause negative cognitive, emotional and behavioural responses both during development and throughout life. Early severe or prolonged stress programmes the brain so that the person stays in an anxious, hyper-vigilant state, always on the lookout for possible danger, easily and overly panicked potentially for the person's entire life **(Glaser et al., 2006; Taylor et al., 2006; Van der Kolk, 2014; WG3-ch6)**.

Stressors associated with city life have a significant effect on brain development and EF abilities. Findings demonstrate the negative effects of poverty on brain development, particularly on the hippocampus **(Wei, Hao and Kaffman, 2014; Delpech et al., 2016; Dahmen et al., 2018)** and the PFC **(Raver Blair and Willoughby, 2012; Hackman et al., 2015; Ursache et al., 2016; Haft and Hoeft, 2017)**, known

to be sensitive to environmental stimuli. Children living in poverty are exposed to a greater number of stressful events like noise, family conflicts, food insecurity and housing instability, and are therefore more vulnerable.

We emphasize the importance of addressing the negative consequences of early stress and poverty in children. Important steps like early intervention should be taken at home, school or in other communities to improve responsive caregiving, achieve healthier brain development, and improve cognitive and emotional functions for success in school and in life **(WG1-ch3, WG3-ch4)**.

2.8 .4

ACADEMIC STRESS

There are also school-specific types of stress that impact upon brain function and school performance. The issue of stress stemming from pressure to perform in an

> ... available evidence indicates that different indicators of poverty are associated with poorer performance in tasks that demand cognitive control and metacognitive processes, phonological processing, episodic memory and learning.

academic context has been raised by UNICEF as one of the most pressing concerns cited by children in some countries **(Liston, McEwen and Casey, 2009)**. Academic stress can be short term (e.g. exam stress), but this type of stress can also become chronic if experienced on a regular basis. Academic stress can have paradoxical effects on performance: in some cases, it can benefit performance, but it can also be detrimental **(WG2-ch9)**.

2.8 .5

DEPRIVATION

Experiences of deprivation involve the absence of expected environmental stimulation for a developmental stage, as usually happens in contexts of poverty **(Sheridan and McLaughlin, 2014)**. The neuroscientific evidence on poverty confirms that poverty measured in terms of family income, parental education and occupation, and community resources is associated with a diverse set of structural and functional changes in the nervous system **(Noble et al., 2015; Farah, 2017)**. In particular, the aspects of the nervous system most commonly affected are related to executive functions, cognitive and emotional self-regulation, language, and learning **(Noble et al., 2015; Farah, 2017; Stevens et al., 2020)**. At the behavioural level, the available evidence indicates that different indicators of poverty are associated with poorer performance in tasks that demand cognitive control and metacognitive processes (e.g. EF and theory of mind), phonological processing, episodic memory and learning. Without any type of intervention, these effects are observed at least through the first two decades of life. At the neural structural level, different indicators of family socio-economic status (SES) or poverty have been associated with changes in cortical thickness, surface and/or volume of several neural networks involving the hippocampus, amygdala, and prefrontal, parietal and occipital cortices, between one month and sixty-four years of age. At a neural functional level, low

SES or poverty has been associated with changes in the activation of occipital, temporal, parietal and frontal networks during tasks that demand emotional or cognitive control or that place demands on phonological processing during the two first decades of life **(Johnson, Riis and Noble, 2016; Farah, 2017; Chan et al., 2018; WG2-ch7)**.

Evidence from cognitive neuroscience and other disciplines (i.e. education, developmental psychology, sociology and pediatric epidemiology) has allowed the identification of mediating and moderating factors of associations between SES/poverty, the development of self-regulation and EF and mental health **(WG2-ch7)**. Among the most frequently identified factors are: perinatal exposure to infections, legal and illegal drugs, environmental toxins and/ or malnutrition; harsh, punitive or authoritarian parenting, less exposure to rich spoken language, and parents who are too busy and stressed to be the parents they would like to be; unsafe neighbourhoods, violence at

home, exposure to lead or mould, living near sites of high pollution (such as highways, industrial areas or toxic waste sites), food or housing insecurity, lack of access to healthy foods, lack of positive role models; less cognitive stimulation at home and in the childcare system; limited access to quality healthcare or education; lack of community resources such as green spaces, playgrounds or parks; cultural norms, values and expectations; and greater likelihood of exposure to different types of early adversity **(e.g. Maholmes and King, 2012; Yoshikawa et al., 2012; Bradley, 2020; WG2-ch5)**.

Contemporary neuroscientific studies of mediators and moderators of the association between poverty and neural development are at a preliminary stage. The evidence to date has found that socio-economic status moderates the association between neural structures and functions; that neural structures and functions moderate the association between the socio-economic level and self-regulatory performance; that low early-life social class

The evidence to date has found that socio-economic status moderates the association between neural structures and functions ...

Threats, negative life events, exposure to environmental hazards, family and community violence, family separations and moves, and job loss or instability, occur across the socio-economic spectrum.

leaves a biological residue manifested in stress hormone and pro-inflammatory signalling; and that different risk and protective factors mediate the association between socio-economic status and neural structure and function **(Miller et al., 2006; Miller et al., 2009; Farah, 2017)**. This type of evidence has generated the hypothesis that the two pathways by which childhood poverty influences neural development during the first two decades of life are quality of parenting and the home environment and the regulation of the stress response **(Ursache and Noble, 2016)**.

2.8 **.6**

THREATS

Threats, negative life events, exposure to environmental hazards, family and community violence, family separations and moves, and job loss or instability, occur across the socio-economic spectrum **(Maholmes and King, 2012; Yoshikawa et al., 2012)**. The

neural systems associated with the regulation of such types of stressors include the hypothalamic pituitary adrenal axis, the sympathetic-adreno-medullar axis, the amygdala and the PFC, which together interact with the immune and cardiovascular systems. These systems work together to regulate the physiological and behavioural responses to stressors, contributing to the adaptative processes of each individual to their contextual circumstances. In the short term, the activation of these systems serves as an adaptive biological response against stressors. However, under continuous or chronic stress, they may be associated with physiological deregulation with the potential to affect emotional and cognitive performance, and physical and mental health including cardiovascular, respiratory and immunological health in the medium and long term **(Felitti and Anda, 2010; McEwen and Gianaros, 2010; WG3-ch6)**.

Recently, research has begun to study the modulation of epigenetic mechanisms (i.e.

> **In addition to the accumulation of potential risk factors, it is important to consider that each threat or deprivation can co-occur with other types of adversity and/or deprivation ...**

interactions between genetic and environmental factors) during early child development under different rearing and socio-economic conditions, where experiences can alter the expression of DNA. This evidence supports the hypothesis that besides the multiple mediation and moderation factors described for deprivation (see above), epigenetic changes may be involved at least partially in the long-term influences of early experiences **(Gray et al., 2017; McDade et al., 2017; Frías-Lasserre, Villagra and Guerrero-Bosagna, 2018; Jiang et al., 2019; Torres-Berrío et al., 2019; Lang, Del Giudice and Schabus, 2020)**. In addition to the accumulation of potential risk factors, it is important to consider that each threat or deprivation can co-occur with other types of adversity and/or deprivation, such as being orphaned and consequent institutionalization, or exposure to domestic or community violence. In this sense, it is important to differentiate experiences due to lack of material resources from those characterized by the presence of threats to physical integrity **(Sheridan and McLaughlin,**

2014). The current consensus in developmental science is that the association between threats, deprivation and child development is modulated at least by the accumulation of risk factors, the co-occurrence of adversity, the susceptibility of each child to contextual factors, the timing of exposure to adversity, and mitigating or protective factors such as responsive, empathetic parenting **(Stevens et al., 2020)**.
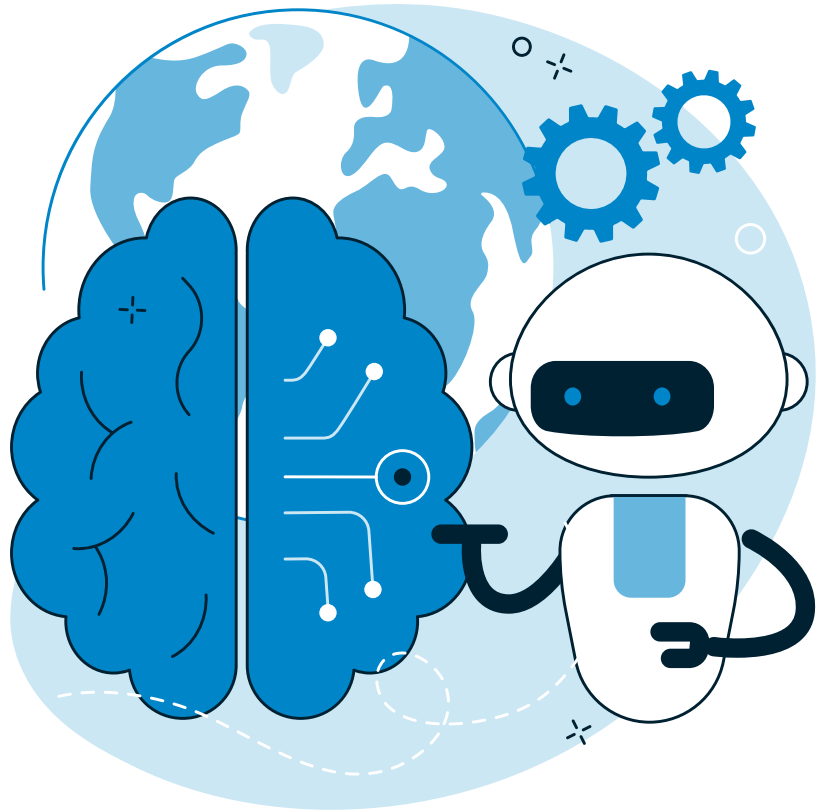
2.9 Debunking neuromyths in education

Neuroimaging techniques can produce valuable insights for researchers seeking to understand the underlying processes by which learning occurs. However, they also frequently find their way into printed and broadcast media, where they feed public fascination with the brain and may be easily misinterpreted. Uninformed interpretation of images showing 'hot spots' can, for example, promote the idea of isolated functional units. Rather than a statistical map showing where activity has exceeded

Attempts to identify neuromyths amongst teachers suggest they are prevalent across diverse cultures.

some arbitrary threshold, non-specialists may see apparently well-defined and static islands on one side of a brain as suggesting localized, specific functions or modules that switch on and off. Considering brain function in terms of independent left and right hemispheres is one example of such misunderstanding. To categorize learners as left-brained or right-brained takes the misunderstanding one stage further. This type of left-brain/right-brain theory is a common example of a neuromyth – defined as a 'misconception generated by a misunderstanding, a misreading or a misquoting of facts scientifically established (by brain research) to make a case for use of brain research, in education and other contexts' **(OECD, 2002, p. 111; WG2-ch7)**.

Attempts to identify neuromyths amongst teachers suggest they are prevalent across diverse cultures **(Howard-Jones, 2014)**. This may reflect the fact that neuroscience is rarely included in the training of teachers, who

are therefore ill-prepared to be critical consumers of ideas and educational programs that claim a brain basis. Concern about neuromyths has contributed to the rationale for several attempts to introduce an understanding of neuroscience into initial teacher education and in-service professional development **(Dubinsky et al., 2019; McMahon, Yeh and Etchells, 2019; Howard-Jones, Jay and Galeano, 2020)**.

Perhaps the most popular and influential myth is that students learn more effectively when they are taught in their preferred learning style. The implicit 'brain-based' assumption appears to be that, since different regions of the cortex have critical roles in visual, auditory and sensory processing, learners should receive information in visual or auditory or kinaesthetic form according to which bit of their brain works better **(Politano and Paquin, 2000)**. The brain's interconnectivity makes such an assumption unsound, and although it is true that some learners learn

A tendency to give greater weight to such biological constraints may contribute to a teacher's sense of powerlessness in relation to supporting their students.

better by either seeing images or listening to verbal instruction, reviews of educational literature and controlled laboratory studies fail to support such an approach **(e.g. Coffield et al., 2004; Kratzig and Arbuthnott, 2006; Geake, 2008; Rogowsky, Calhoun and Tallal, 2020)**.

In recent years, the term 'neuromyth' has been criticized as tendentious **(Gardner, 2020)** while other researchers have questioned the extent to which teachers' beliefs in neuromyths has significant implications for classroom practice and students' learning. For myths that are closely related to practice (e.g. learning styles) such implications might appear self-evident, since few teachers would voluntarily implement an approach they believe to be ineffective. The implications of neuromyths about general brain function, such as the belief that we only use 10 per cent of our brain, are less clear. Krammer, Vogel and Grabner **(2021)** find no association of neuromyth belief on academic outcomes in a teacher training course, although this study does not assess teaching practice.

Horvath et al. **(2018)** explore whether belief in neuromyths predicted whether a teacher won an award and fail to find such evidence for most myths included in their study. The researchers do, however, find that underestimating brain plasticity (in relation to second-language learning and believing in critical periods after which children cannot learn certain things) appears to be a negative predictor of an award. A tendency to give greater weight to such biological constraints may contribute to a teacher's sense of powerlessness in relation to supporting their students. Belief that genes exert more influence than environment on cognitive ability has been found to be associated with an entity theory of intelligence which posits that our intelligence is set at birth and cannot be changed **(Crosswaite and Asbury, 2019)**. These two neuromyths may be very detrimental since teachers who have knowledge about brain plasticity induce a growth mindset on motivation and academic achievement and are more prone to having a pedagogical stance

> **The fact that learning can change and reconfigure the brain, at all ages, in infants, children and even adults, is a fundamental theoretical discovery that has important implications for educational practices.**

adapted to student needs **(Sarrasin et al., 2018; Canning et al., 2019)**. The fact that learning can change and reconfigure the brain, at all ages, in infants, children and even adults, is a fundamental theoretical discovery that has important implications for educational practices. Promoting to teachers, and also to students, this malleable representation of intelligence, of a brain sculpted by education and culture, which means that nothing is decided in advance, is an extremely powerful leverage for education.

When identifying neuromyths that should be addressed in teacher education, the potential relevance of each myth to classroom practice should be considered.

2.10 Key findings

- Neuroscience, complementary to psychology, can inform education on how learning works and how learning is constrained by brain function and structure.

- Several physiological factors (e.g. nutrition, exercise, pollution and sleep) have effects on the brain and therefore on learning.

- Several social factors (e.g. stress, social interactions and cultural environment) have effects on the brain and therefore on learning.

- Human brain development is a complex, dynamic, continuous and non-linear process that begins during the first weeks of gestation and lasts until early adulthood.

- Brain plasticity is very important during childhood and adolescence and plays a key role in cognitive development and learning.

- Subtle variations of the in utero environment can have long-term effects on cognitive abilities

2.11 Recommendations

- Include neuroscience in the training of teachers.

- Identify and popularize among teachers and parents the factors that have effects on the brain and on learning.

- Provide access in the school setting to adequate support for physiological needs that promote learning, such as pre- and post-training sleep, nutrition and exercise.

- Identify social factors that impair learning (trauma, poverty, deprivation, threat, academic stress) and provide psychological support in the school setting to mitigate their effects.

- Identify and debunk neuromyths in education.

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CHAPTER

3

Individual differences and influences on learning

This chapter should be cited as:

This chapter assesses the biological, psychological and social factors that contribute to individual differences in learning. Recent research suggests individual differences emerge from complex interactions between these factors. Here the focus is on reciprocities across the different levels and exploring the controversies and convergences across different disciplines. Cross-disciplinary research can lead to innovations in the science of learning. For example, culturally sensitive conceptualizations and assessments of psychological processes acknowledge the interactions between individuals' cognitive development with the socio-political factors that shape their environments. The findings caution against policy interventions that focus on a single assumed causal factor because educational outcomes cannot be predicted by one factor alone. Future research and policy should account for the interacting 'bio-psycho-social' (Youdell et al., 2020) factors that influence individual differences in education.

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3.1

Introduction

In recent years, significant attempts have been made to develop cross-disciplinary research alliances across the biological, psychological and social sciences. Broadly, as the biological and psychological sciences have moved towards a more social view of biological and psychological processes, the social sciences have also begun incorporating biological and psychological conceptualizations into their studies. The drivers of these fresh connections have included a number of scientific reconceptualizations of various aspects of human life, enabled in large part by technological and methodological advances such as genetic sequencing, psycho-physiological and biometric monitoring, and neuroscientific brain imaging. These include advances in molecular genomics and the recognition that genomic functioning is profoundly affected by social forces, environmental contexts and experiences. Social neuroscience has explored the ways in which brain structure and functioning are affected by social and environmental factors. Social psychology, too, has long examined how individual thoughts and cognitive processes are shaped by social, cultural and political contexts, interactions and influences.

The combination of genetics and social science to address education research questions and problems represents an emerging frontier of investigation and knowledge production.

Meanwhile the social sciences have begun exploring how biological and psychological factors interact with social phenomena. Such approaches include the involvement of sociologists in analyses of the interactions of socio-economic status with 'genomic reactivity'; engagement from social science with the ways in which social contexts and environments impact on bodies through processes of neural, cognitive and genomic plasticity; the emergence of interdisciplinary fields such as sociogenomics, environmental epigenetics, social epidemiology, and their role in understanding the social and biological factors involved in health, illness and socio-economic outcomes; and, more broadly, social scientific re-theorizing of the complex relations between 'nature' and 'nurture', 'biology' and 'culture', and 'bodies' and 'experiences' **(Meloni et al., 2018)**.

However, significant disciplinary differences persist across the biological, psychological and social sciences, especially in relation

to questions over individual differences. These differences are especially evident in the field of education research, which by its nature encompasses diverse perspectives including sociology, philosophy, psychology and policy studies, as well as newer research endeavours such as educational neuroscience and the genetics of education. The central concept of learning is itself understood and approached differently by researchers from these disciplinary areas.

The purpose of this chapter is to explore emerging research that troubles hard internal/external divisions in how we conceive of individual differences in learning and educational outcomes, while acknowledging that there remain many unresolved tensions and conflicts in developing such multifaceted conceptions of individual difference and learning. The contributing authors discuss both the factors that are intrinsic to the person, which can influence learning, and how these interact with external factors

3

CHAPTER

Over the two decades since the sequencing of the entire human genome, genetic sciences and their experimental techniques have opened up the human body to unprecedented levels of analysis at the molecular scale, and paved the way for new forms of diagnosis, prediction and treatment.

in bidirectional, intersecting and transversal ways. Based on the collected perspectives in the chapter, we consider the prospects for future learning research and policy to take account of the intersecting and interacting 'bio-psycho-social' factors that shape individual differences **(Youdell et al., 2020)**, while taking very seriously the scientific, ethical and political implications of such biosocial conceptualizations **(Roberts and Rollins, 2020)**.

The following section focuses on the 'molecular' level of genes and their interaction with external environments, with contributions from behavioural genetics and social genomics. The key question addressed is: what are the genetic sources of individual differences and gene-by-environment interactions that contribute to individual differences, and what controversies and ethical tensions need to be negotiated regarding genetic explanations of learning for educational policy and/or practice? **Section 3.3** then focuses on psychological traits and states

of individual difference, asking: how do individual differences in cognition, mindset, executive function and character influence learning, how have these psychological conceptions been deployed as policy solutions, and what tensions emerge when such psychological concepts are made policy-relevant? **Section 3.4** then focuses on the external social, cultural and environmental factors involved in individual difference, and draws on recent research seeking to identify productive inter-/ transdisciplinary ways to account for biological, psychological, social and material interactions in the individual's learning experience. In the conclusion, we consider the implications of this research, addressing reciprocal interactions between molecular biological processes and functions, psychological dimensions of individual difference, and their intersections with social and environmental factors related to learning.

3.2 Molecular individual differences

Over the two decades since the sequencing of the entire human genome, genetic sciences and their experimental techniques have opened up the human body to unprecedented levels of analysis at the molecular scale, and paved the way for new forms of diagnosis, prediction and treatment **(Parry and Greenhough, 2018)**. While for some the data-intensive genomics revolution of the early twenty-first century promises great hope, such as the potential for 'precision medicine' tailored to the individual genome, for others it anticipates the return of hard biological perspectives on human lives and bodies, even perhaps new forms of eugenic discrimination based on individualized genomic screening and intervention **(Rose, 2007; Prainsack, 2017)**.

Within education, new research

... the emphasis is on bidirectional interactions between biological processes and social environments rather than internal 'genetic architectures' alone.

focuses on the molecular genomic underpinnings of individual difference, learning and educational outcomes, as detailed in the following sections. This genetics-based research related to education takes different forms, with varying degrees of sensitivity to environmental influence and interaction, and highly divergent ideas about its relevance for policy or practice **(Youdell and Lindlay, 2019; Williamson, 2020)**. Across these emerging studies, the emphasis is on bidirectional interactions between biological processes and social environments rather than internal 'genetic architectures' alone.

The combination of genetics and social science to address education research questions and problems represents an emerging frontier of investigation and knowledge production. The purpose of this section is to summarize the key findings, as well as the substantial gaps that remain in understanding the gene–environment interactions underpinning learning outcomes, and the very urgent ethical and

political debates that such studies raise. We specifically address the genetics of learning, including recent results from twin studies and genome-wide polygenic scores (PGSs), as well as the possible policy implications, controversies and ethical tensions in this emerging field of molecular education research.

3.2 .1

THE GENETICS OF EDUCATION

Research in the genetics of education has a long history, stretching back to the eugenics movement and intelligence quotient (IQ) testing at the beginning of the twentieth century, encompassing biologically determinist accounts of racial differences in intelligence in the second half of the century, and extending to advances in molecular genomics in the twenty-first century **(Martschenko, Domingue and Trejo, 2019)**. Today, in the post-

genomic era after the sequencing of the human genome, a new form of genetics-based research on learning and education is taking place. It is led by researchers in the fields of behavioural genetics, which combines psychological and genomic forms of analysis **(Harden, 2021)**, and social genomics, where genomics methods and insights converge with social scientific modes of analysis **(Mills and Tropf, 2020)**. This recent interest in the genetic and social factors involved in learning and education is characterized by ongoing conflicts between social and behavioural genomics researchers who see a new horizon for innovative research on education and learning in the human genome **(Cesarini and Visscher, 2017; Conley and Fletcher, 2017)**, and those who perceive it as a potentially dangerous return to eugenicist forms of biological determinism that have historically fixed differences and separated students along lines of 'natural' intelligence, race, ability, gender and so on **(Panofsky, 2015; Bliss, 2018)**.

According to research from the field of behavioural genetics, people learn differently, and one source of difference between them is their genes. The emphasis in such studies is on the heritability of outcomes. Here, heritability is defined as the proportion in the difference of life outcomes in a population that is due to genetic inheritance, rather than assuming simple intergenerational replication of behaviours or outcomes **(Tucker-Drob et al., 2016; Harden, 2021)**. Until recently, behavioural geneticists' major tool for estimating the impact of genetic differences between people was twin studies **(Polderman et al., 2015)**. Over a century of twin research has focused on learning, specifically measurable learning outcomes. Twin studies indicate that genetic influences on educational outcomes are partially mediated through genetic influences on cognitive abilities, but also through traits and characteristics that are often broadly referred to as 'non-cognitive skills', such as

> … people learn differently, and one source of difference between them is their genes.

... there is remarkable consistency in findings that both genetic and environmental influences matter.

intellectual curiosity, delay of gratification, motivation and persistence **(Rimfeld et al., 2018; Tucker-Drob et al., 2016)**.

Across all these learning outcomes, there is remarkable consistency in findings that both genetic and environmental influences matter. On average, twin studies report that genetic influences account for around 40 to 80 per cent of individual differences on a learning outcome, and environmental influences account for around 20 to 50 per cent of individual differences **(e.g. de Zeeuw, de Geus and Boomsma, 2015; Silventoinen et al., 2020)**. Regardless of the differences in overall magnitude of genetic and environmental influences for each learning outcome, twin studies report it likely that the same genes (in the twin modelling sense, as in the same general genetic influences on individual differences), and potentially the same environments, influence all these learning outcomes **(Plomin and Kovas, 2005)**. In addition, the

same genes influence difficulty in a learning outcome as typical ability **(van Bergen, van der Leij and de Jong, 2014)**. Recent specialized twin models allow researchers to move beyond estimating the general genetic and environmental influences on a learning outcome, and instead to specify exactly what and how the environment influences learning outcomes, such as the effects of socio-economic status, household environment **(Hart et al., 2007)**, neighbourhood environment **(e.g. Little et al., 2019)**, and classroom and school environment **(Taylor et al., 2010)**. Other approaches use quasi-experimental methods to understand causal relations underlying a correlation between a learning outcome and an environmental influence **(van Bergen et al., 2018; Erbeli, van Bergen and Hart, 2019)**.

The most important conclusion from this body of twin research is that it is not simply a question of nature versus nurture but that learning occurs as a result of the

interplay between nature and nurture functioning within an integrated framework. Knowing how this integrated framework operates is crucial for the development and improvement of effective learning support. However, significant controversy remains over whether twin studies overestimate heritability for social and behavioural traits **(Young, 2019)**; sufficiently account for other contextual specifics **(Tucker-Drob and Bates, 2016)** or the age of the twins in the twin sample **(Little, Haughbrook and Hart, 2017)**; and how specific skills are measured within each learning outcomes **(Hart et al., 2009, 2013)**. Thus, while behavioural genetics reports consistent evidence that a significant proportion of learning and educational outcomes is due to genetic heritability **(Rimfeld et al., 2018)**, some of the variability in outcomes is due to gene–environment interactions, for example, individual genetic makeup interacting with educational contexts **(Dick et al., 2015)**, further mediated by

country-specific socio-economic factors **(Plaut et al., 2017)**.

3.2 .2

GENOME-WIDE POLYGENIC SCORES

Attempts to examine the interaction of an individual's genetic makeup with their environment began in earnest in the early 2000s. Over the last decade, a paradigm shift has occurred in the analysis of heritability, particularly as social scientists, economists and political scientists have begun adding genomic data to the other social variables they study **(Conley and Fletcher, 2017)**. Technological advances allowing researchers to measure the human genome directly have been employed by behavioural genetics researchers seeking to validate the core twin studies conclusion that people differ in their learning outcomes because of differences in their inherited DNA sequence

… significant controversy remains over whether twin studies overestimate heritability for social and behavioural traits.

... polygenic score (PGS) indicates an individual's genetic propensity toward a specific outcome.

variation **(Plomin and von Stumm, 2018)**. Concurrently, new research teams and consortia have begun to develop 'social science genomics' approaches **(Mills and Tropf, 2020)**. Recent high-profile book publications introducing core ideas and policy implications of this work for education have led to significant mainstream media coverage, as well as scientific controversy and ethical debates **(Panofsky, 2015; Comfort, 2018; Henn et al., 2021)**.

Behavioural and social genomics research is enabled by the possibility of conducting genome-wide association studies (GWAS). GWAS is a research method that searches and compares DNA markers across the entire genome **(Pearson and Manolio, 2008)**, utilizing highly complex research set-ups that include vast databanks of genotyped data, laboratory hardware, bioinformatics software and statistical techniques **(Conley and Fletcher, 2017; Williamson, 2020)**. Such studies test associations with up to millions of measured

genetic variants called single nucleotide polymorphisms (SNPs) **(Visscher et al., 2017)**. Using GWAS results, information about the SNPs in a person's genome can be aggregated into a single number, called a polygenic score (PGS), which indicates an individual's genetic propensity toward a specific outcome **(Belsky and Harden, 2019)**. Genome-wide PGS approaches recognize that all variations in human behavioural traits are influenced by hundreds or thousands of genetic variants, each with tiny effects **(Harden and Koellinger, 2020)**. However, they are limited to historical population samples of adults of European ancestry and therefore cannot be considered fully representative or generalizable to other population groups **(Herd, Mills and Dowd, 2021)**.

Research on the polygenicity of learning outcomes is now at the forefront of genetic research in education, with studies compiling huge samples of data from over a million people **(Harden, 2021)**. By studying SNPs, social and

behavioural genomics scientists have identified specific regions of the genome that are associated with outcomes such as cognitive test performance and years of educational attainment **(Lee et al., 2018)**, with some research teams suggesting GWAS can reveal the genetic architecture of intelligence **(Malanchini et al., 2020)**. According to recent studies, among people with European genetic ancestry, PGSs are as strongly correlated with educational outcomes as other variables traditionally used in learning research – such as family income – showing that the influence of all genetic variations together captures up to 15 per cent of the overall variance in educational attainment **(Lee et al., 2018)**. Researchers report that roughly half of these polygenic effects are indirect, operating via the environment that parents generate and provide for their children **(Koellinger and Harden, 2018; Kong et al., 2018)**. These methods have been used to predict educational achievement on national standardized

examinations **(von Stumm et al., 2020)**. GWAS have also been conducted on other education-related behaviours and outcomes including attention deficit hyperactivity disorder (ADHD) **(Demontis et al., 2017)**, obsessive compulsive disorder (OCD) **(Ritter et al., 2017)**, dyslexia **(Gialluisi et al., 2019)** and mathematical ability **(Chen et al., 2017)**.

Recent work also shows that individuals' genome-wide PGSs are correlated with their learning environments through a wide variety of direct and indirect mechanisms. Factors associated with completed education in European ancestry populations are correlated with schooling environment and developmental learning trajectories **(Lee et al., 2018; Belsky and Harden, 2019)**. Parents' genetic measures work through both transmission of genetic makeup and the creation of the environment to influence educational outcomes **(Belsky et al., 2018)**. Consistent with results from twin research, measured DNA

Factors associated with completed education in European ancestry populations are correlated with schooling environment and developmental learning trajectories.

> ... it is important to realize that even the best currently available PGS is not useful for 'predicting' the educational outcomes of specific individuals.

variants are also associated with educational outcomes not just because they relate to cognitive abilities, but because they relate to individual differences in 'non-cognitive' skills **(Demange et al., 2021)**.

Irrespective of whether genetic effects are direct or indirect, it is important to realize that even the best currently available PGS is not useful for 'predicting' the educational outcomes of specific individuals. In addition, the portability of PGSs for educational attainment to different environments and different ancestry groups is very limited, and there remain limitations in understanding the causal processes that drive the observed associations **(Duncan et al., 2019; Lee et al., 2018; Martin et al., 2019; Rosenberg et al., 2019)**. Thus, within behavioural and social genomics, it is recognized that more discovery work with datasets on multiple populations, children and adolescents is needed, along with better methodologies and interventions to account for gene–

environment correlation **(Fletcher and Conley, 2013; Harden, 2021)**.

Moreover, within the field of behavioural and social genomics calls have been issued to employ more sophisticated conceptualizations of 'environmental' influence, by drawing further on social science and sociological theory **(Mills and Tropf, 2020)**. From this perspective, one important critique of behavioural and social genomics is that it treats the 'environment' in 'atomistic' psychological terms such as influence of family, neighbourhood or school environment, whereas more sociologically informed analysis would highlight historical and social forces, social structures such as race, gender and class, and their complex influence on the genetic factors involved in learning processes and educational outcomes **(Herd, Mills and Dowd, 2021)**.

3.2 .3

CONTROVERSIES AND ETHICAL CHALLENGES OVER THE NEW GENETICS OF EDUCATION AND INTELLIGENCE

The re-convergence of molecular genetic research with education research is shaping what it means to learn, educate and progress through education. The increasing prominence of molecular genetic research in education brings both perils and promises that should be considered alongside each other. Importantly, and to reiterate, recent GWAS-based studies related to educational outcomes are primarily conducted using DNA samples from individuals of European genetic ancestry and focus on individual-level differences **(Popejoy and Fullerton, 2016)**. This means that GWAS

This means that GWAS data should not be used to make comparisons between groups, particularly groups defined by categories of ethnicity.

data should not be used to make comparisons between groups, particularly groups defined by categories of ethnicity **(Herd, Mills and Dowd, 2021)**. Moreover, PGSs cannot 'predict' educational or other life outcomes for an individual accurately, and cannot cleanly separate genetic and environmental influences on those outcomes either **(Harden and Koellinger, 2020)**.

Despite the limitations of GWAS, calls for the incorporation of genetic data into education policy and practice have proliferated over the last decade **(Asbury and Plomin, 2013; Thomas et al., 2015; Kovas et al., 2016; Malanchini et al., 2020)**. Some researchers argue that genomic data can be used in social science research to better understand patterns of human behaviour and to evaluate and design more effective public policies, including education policies. Some have suggested that PGSs, in tandem with existing screening and progress monitoring technologies

3

CHAPTER

... very real ethical problems associated with differentiating students by biological measures of ability.

used by schools, could be used as an additional 'screening' tool to identify 'learning disabilities' and differentiate instruction for students **(Shero et al., 2021)**, although the feasibility of doing so remains questionable given the current partiality of available data and the very real ethical problems associated with differentiating students by biological measures of ability **(Roberts and Rollins, 2020)**.

More controversially still, other researchers believe genetic data might intersect with education policy through an approach termed 'precision' education **(Asbury and Plomin, 2013; Sokolowski and Ansari, 2018)**. Precision education, like precision medicine **(Ashley, 2015; Porche, 2015)**, focuses on the individual and the idea of devising specially tailored interventions based on individual-level genotyped data. Proponents of this model argue that policy-makers, schools, students and families would benefit from the ability to learn from a child's genetic data and

create individualized education plans and interventions that maximize students' strengths and minimize their weaknesses **(Asbury and Plomin, 2013)**. At the heart of precision education is the belief that integrating genetics into education research could optimize educational processes **(Kovas et al., 2016)** or help to identify learning disabilities **(Hart, 2016)**.

Despite debate over the methodological feasibility of precision education **(Shero et al., 2021)**, some researchers have put forth policy proposals for the creation of 'genetically sensitive' school systems **(Asbury and Plomin, 2013)** and the subject is entering the Western public domain **(Briley and Tucker-Drob, 2019)**. The very idea of personalized, precision education is, however, highly contested even within the fields of behavioural and social genomics **(Harden, 2021; Herd et al., 2021)**, and is the subject of criticism from ethical, scientific and social science perspectives **(Panofsky, 2015; Comfort, 2018; Williamson, 2020)**. Behavioural

and social genomics researchers themselves have raised concerns about over- or misinterpretation of their findings, highlight the many persistent gaps in knowledge, and the potential deleterious consequences of moving too fast from basic research to practical or policy application in the field of education **(Conley and Fletcher, 2017)**.

The many possible applications of genome-wide association studies and PGSs in education and education research raise many other concerns over the misuse and misapplication of molecular genetic research in education **(Asbury, 2015; Sabatello, 2018; Martschenko, Trejo and Domingue, 2019)**. An ugly history of using eugenic ideologies to justify race and class based differences and legitimize state-sanctioned violence **(e.g., Buck v. Bell 1927)** raises important ethical, social and policy questions about how to pursue equitable public education in the post-genomic era. Such concerns include whether

genetic research into socially valued behaviours like intelligence will intensify social inequalities **(Roberts, 2015)**, exacerbate bias and stigma **(Sabatello, 2018; Matthews et al., 2021)** or confine children to certain educational tracks that limit their agency.

In social environments built on systemic inequality and the continual disempowerment and marginalization of racialized groups, molecular genetic data could obscure ethical uncertainties, re-solidify sociocultural assumptions and resuscitate mythologies about inherent racial differences **(Roberts and Rollins, 2020)**. Moreover, a focus on genetics could detract from important social and environmental factors that impact student learning and achievement **(WG2-ch1)**. Any educational policy approach based on PGS values would run a substantial risk in perpetuating environmentally induced disadvantages of children or targetting the wrong cause for individual differences in schooling

The very idea of personalized, precision education is, however, highly contested even within the fields of behavioural and social genomics.

3

The education research community should be proactive in avoiding past patterns of injustice and opening up interdisciplinary collaborations that keep equity in mind.

outcomes. Further, using PGSs to rank, sort and target children would involve a substantial risk in stigmatizing and demotivating those with low score values. Very little is currently known about how people react to information about their PGS values. One of the first studies that investigated how people react to learning their genetic risk for disease found that the effects of the perceived genetic risk were often self-fulfilling and sometimes greater than the effects associated with actual genetic risk **(Turnwald et al., 2019)**. Thus, informing children, parents and teachers about potential genetic influences on education may have unintended and undesirable effects. These possibilities raise questions about whether the risks of genetic research into socially valued behaviours and outcomes outweigh the potential benefits. The education research community should be proactive in avoiding past patterns of injustice and opening up interdisciplinary collaborations that keep equity in mind. Failure to do so would

be a disservice to students, particularly those who are most underserved.

In sum, the development of molecular genomics in education research is controversial, owing to the history of biological discrimination stemming from the genetic sciences and the proliferation of biodeterminist myths of intelligence and outcomes. Such myths include the ideas that: (1) genetically influenced outcomes are 'innate' or 'hard-wired'; (2) social policy and environmental interventions will be ineffective for changing genetically influenced outcomes; (3) genetic influences explain racialized disparities in learning outcomes; and (4) genetic research validates existing social hierarchies. None of these myths survive scientific scrutiny. Consequently, scientists working in this area have a special responsibility to communicate their results responsibly and to combat commonly held myths about biodeterminism.

3.2 .4

SUMMARY

Molecular genomics has begun to identify specific associations between genetic variants and education-related behaviours and outcomes, and scientists claim modest causal genetic effects on learning. Many of the studies identified in this section are sensitive to the complex interactions of genes with environmental factors, and, in contrast to some well-publicized claims, do not report DNA to work as a 'blueprint' for success in education, intelligence or achievement. One's genetics do not determine one's educational outcomes, but according to much of the research reported above, they are associated with those outcomes in complex, bidirectional interactions with social and institutional environments. The findings provide scientific evidence challenging claims that generating PGSs for individual students could be used for 'personalized' or 'precision' education that is modified according to students' individual genetic differences and propensities.

Nonetheless, the science reported in this section remains 'in progress' and much more is yet to be understood about both the genetic mechanisms and environmental influences that shape educational and learning outcomes. Despite varied proposals to employ genetic data for educational practice or policy, no current scientific consensus exists on how such data might be used in educational institutions or by policy-makers. Too many political, ethical and scientific problems remain unresolved – and may not be resolvable in any meaningful sense – for social and behavioural genomics to be treated as a source of immediate policy-relevant knowledge and insight into the individual differences underpinning learning and educational outcomes.

One's genetics do not determine one's educational outcomes, but according to much of the research reported above, they are associated with those outcomes in complex, bidirectional interactions with social and institutional environments.

3.3

Psychological individual differences

Children's educational outcomes depend on multiple, interacting cognitive systems that underpin learning across development. Broadly, some of the key cognitive processes that support a child's educational journey include language, memory and executive functions (EF), and higher-order processes such as critical thinking and reasoning. Learning is supported by this array of cognitive processes that must be coordinated and that explain individual differences in learning outcomes. In tandem with these cognitive processes, individual differences in psychological factors such as children's motivation and self-regulation support foundational academic skills such as literacy and numeracy. Literacy and numeracy skills, which are highly correlated

Children's developing memory systems also support learning through their capacity to map new meanings and discover new patterns, which are associated with explicit and implicit learning, respectively.

throughout development, predict later academic success **(e.g. Ritchie and Bates, 2013)**. Literacy and numeracy are keys that unlock other learning opportunities and accompany children throughout their entire education journey, supporting their transition from primary to secondary and tertiary education.

Mastery of literacy and numeracy, key targets of primary schooling, are directly supported by core cognitive components that allow children to decode written language and master numerical concept **(e.g. Best, Miller and Naglieri, 2011; Fuhs et al., 2014; Earle et al., 2020; Jasiska et al., 2021; Spiegel et al., 2021)**. Children's language abilities, including phonological awareness (the awareness of the sounds that make up one's language) and vocabulary, are the critical foundation for later literacy and numeracy skills **(e.g. Wagner and Torgesen, 1987; Goswami and Bryant, 1990; Korpipää et al., 2017; Cirino, Child and Macdonald, 2018)**. Children's developing memory systems also support learning

through their capacity to map new meanings and discover new patterns, which are associated with explicit and implicit learning, respectively **(Squire, 1992; Squire and Dede, 2015)**. Their EF further enable children to allocate their attention to relevant information in their environment, and maintain and manipulate that information in real time, while retaining the ability to incorporate new rules and new information; these abilities enable complex critical thinking, problem-solving and reasoning skills, and self-regulation, motivation and persistence. These abilities shape how children engage with teachers, peers and instructional content, indirectly contributing to their academic outcomes, as well as their social and emotional development. Recent research has accumulated a greater understanding of the sources of individual differences in children's cognitive development, and some of the key findings are highlighted in the following sections.

Researchers in the developmental cognitive sciences have

The ability to detect whether a child is at risk of experiencing difficulties in reading or mathematics before that child even starts school clearly has potential benefits...

tracked children's individual developmental trajectories in relation to their learning outcomes, which has led to, among many things, a growing understanding of risk factors that increase the likelihood of children failing to realize their educational potential, as well as protective factors that increase the likelihood of positive educational outcomes. Research, including from the cognitive neurosciences, has found that early neurocognitive individual differences predict children's later academic attainment **(e.g. Supekar et al., 2013; Jasiska et al., 2021)**. These findings hint at the promise of highly individualized learning plans or intervention, where educational experiences may be customized based on individual psychological differences detected in early childhood using the latest developmental cognitive science tools, including neuroimaging methods. The ability to detect whether a child is at risk of experiencing difficulties in reading or mathematics before that child even starts school clearly has potential benefits; early detection

has the potential to lead to early intervention at a time in a child's development when their brains are most plastic and therefore more receptive to intervention **(see WG3-ch6 on learning disabilities)**. Yet, this potential application is not without controversy. There are no guarantees that a child who exhibits cognitive risk factors will suffer from deficits that impact learning later in development. Identifying children as at-risk also carries the risk of early categorization and stigmatization that may not be warranted by the potential benefits.

Individual differences in learning outcomes are strongly related to individual psychological differences, and much of the recent scholarship on individual differences in cognition and in learning has examined the extent to which individual differences are influenced by genetic and environmental factors, and gene environment interactions; however, this field of research is only beginning to understand the complex relationships between

> **... cognitive development is both vulnerable to the negative effects of an impoverished and/or adverse environment, as well as responsive to intervention.**

genes, environment, and child development and learning. It is nonetheless clear that multiple aspects of cognition remain malleable to environmental influences throughout childhood. Practically, this means that cognitive development is both vulnerable to the negative effects of an impoverished and/or adverse environment, as well as responsive to intervention. Both 'sides of the plasticity coin' have direct relevance to education and social policy.

3.3 .1

INDIVIDUAL DIFFERENCES IN COGNITION AND LEARNING

Learning is a dynamic, iterative process that is simultaneously affected by individual and environmental factors, as well as the interaction between them. The core of these interactions is social in nature – learning is

a social process. In a classroom context, these interactions are primarily with peers **(e.g. Vygotsky, 1978)** and teachers **(Hamre and Pianta, 2001)**. Learning itself changes the physical structure of the brain, and the changing structure in turn organizes and reorganizes how the brain functions **(Zatorre, Fields and Johansen-Berg, 2014)**. Two key sets of processes that are related to higher-order or deeper learning and complex skills such as critical thinking and reasoning are self-regulatory and motivational processes. Both are malleable to intervention, and both are linked to children's resiliency in high-risk environments **(e.g. McCoy, Gonzalez and Jones, 2019)**.

Self-regulation includes skills to regulate behaviour, emotions and thoughts in the pursuit of long-term goals, and the ability to delay gratification, pay attention and control impulsivity. Self-regulated learners apply these skills to the learning process and are guided by metacognition and reflection to achieve their goals. EF – a component of self-regulation –

Growth mindset – the belief that intellectual abilities can be developed – can be taught and has been shown to improve academic outcomes.

are culturally universal skills that enable individuals to control their impulses, ignore distracting stimuli, hold relevant information in their mind, and shift between competing rules or attentional demands **(Obradovic and Willoughby, 2019)**. EF support classroom engagement and academic learning **(Jacob and Parkinson, 2015)**. Relatedly, 'grit' includes the persistence and passion that underlie goal-oriented behaviours towards a larger superordinate goal and has been linked to learning in several contexts **(e.g. Duckworth et al., 2011)**. Self-regulation and grit are strongly correlated but are not the same **(e.g. Oriol et al., 2017; Usher et al., 2019)**.

Motivation also plays an important role in learning throughout the lifespan and activates and sustains behaviour towards a goal. A key factor in motivation is an individual's mindset: beliefs about the nature of human attributes (e.g. intelligence) that affect one's actions **(Dweck, 1999)**. Growth mindset – the

belief that intellectual abilities can be developed – can be taught and has been shown to improve academic outcomes in a nationally representative sample of adolescents in the United States (USA) **(Yeager et al., 2019)**. Motivations and mindsets are distinguished from general cognitive functioning and help explain achievement independent of intelligence test scores **(e.g. Murayama et al., 2013)**.

Both self-regulatory and motivational processes are malleable and should not be construed as fixed 'traits'. On the one hand, cumulative risk and the associated psychosocial stress **(Evans and English, 2002)** can affect the neural networks that underlie EF and self-regulation **(Blair, 2010)**. On the other hand, both can be improved in positive learning environments **(Renninger and Hidi, 2006; Diamond et al., 2007)**. For example, motivation develops throughout life and changes based on experiences with learning and other circumstances **(Turner and Patrick, 2008)**. Equitable learning

Individual variation in EF has been associated with learning-related outcomes such as school readiness, academic achievement and social competence in both high- and low-and-middle-income country settings.

outcomes for all groups of children cannot be achieved without assessing and addressing children's risk experiences. Targeting both environmental improvements and the development of self-regulation and motivational processes would greatly enhance children's learning opportunities.

Optimal learning rests on a wide range of inputs, such as adequate nutrition, exposure to language and a responsive caregiver. Exposure to risk in children's environments affects these inputs and is linked to poorer higher-order cognitive processes and learning outcomes. Risk factors can be in the form of a single event that severely disrupts a child's environment or they can be prolonged over an extended period of time. It has been argued that cumulative risk models – those that count risk factors in an additive manner – provide a more comprehensive representation of overall levels of adversity and capture how stress overwhelms children's adaptive systems **(Luthar, 1993; Evans, Li and Whipple, 2013)**. A

cumulative risk index has been found to explain substantially more variance in children's development and learning than a single risk factor alone **(Sameroff et al., 1987, 1993)**.

3.3 .2

EXECUTIVE FUNCTIONS

EF are universally relevant cognitive skills – working memory, inhibitory control and cognitive flexibility – that collectively enable children to focus attention, regulate impulses, switch between competing demands and engage in goal-directed activities. Individual variation in EF has been associated with learning-related outcomes such as school readiness, academic achievement and social competence in both high- and low-and-middle-income country settings **(Zelazo et al., 2016; Obradovi and Willoughby, 2019)**. Developed across the life course, EF are shaped by contextual factors, including experiences

... low-burden, flexible executive function strategies can be adapted to individual and place based needs and embedded with children's daily academic routines.

of stress and adversity resulting from systemic racial, social and economic inequalities **(Blair and Cybele Raver, 2012; Raver and Blair, 2020; WG2-ch5; WG3-ch5)**. It is paramount that we both reduce children's exposure to structural risks and foster opportunities to strengthen EF. The most effective interventions related to EF: (1) feature explicit cognitive training; (2) go beyond rote practice to continually challenge students' EF; (3) are implemented in a consistent, prolonged way; and (4) are adapted for use across diverse cultural contexts **(Diamond and Ling, 2016)**. Instead of using standalone EF programmes, which are often costly and challenging to scale, educators can integrate 'kernels of practice' – low-burden, flexible executive function strategies that can be adapted to individual and place based needs and embedded with children's daily academic routines **(Jones et al., 2017)**. To evaluate whether these approaches are working equitably, we must also design and utilize classroom based executive function assessments that capture unique sociocultural experiences that foster EF, celebrate culturally

The global education community would also benefit from the creation of more developmentally appropriate, culturally sensitive direct assessments of students' motivation-related behaviours.

relevant expressions and applications of EF, and produce accessible, actionable data for educators **(Sarma and Mariam Thomas, 2020; Obradovi and Steyer, 2021)**.

Given that learning involves a combination of 'skill' and 'will', children's motivation to engage, invest effort, and seek out and persist through challenges influences their use of cognitive skills like EF as well as their classroom based experiences and behaviours. Individual differences in motivation are related to key elements of learning, including focus, creativity, confidence and achievement **(Patrick, Turner and Strati, 2016)**. Rather than being conceptualized as a character trait, with students deemed 'more' or 'less' motivated, motivation is now recognized as situated and malleable across environments and instructional activities.

To ensure that all students are motivated to learn and not discouraged by mistakes, we should seek to remedy the inequitable contextual supports

and discriminatory expectations that contribute to students' displays of low motivation and avoidance of failure **(Oyserman and Destin, 2010; Zusho, Daddino and Garcia, 2016)**. Indeed, programs and policies that promote (1) inclusive classroom climates and a sense of belonging, (2) supportive relationships with teachers and peers, (3) culturally responsive pedagogical approaches that affirm students' cultural identities and modes of learning, promote agency, and develop socio-political consciousness, and (4) positive racial and ethnic socialization have been linked to increased student motivation, particularly among historically marginalized populations **(Aronson and Laughter, 2016; Gregory and Korth, 2016; Wentzel and Muenks, 2016; Zusho, Daddino and Garcia, 2016; Gay, 2018; Kumar, Zusho and Bondie, 2018)**.

The global education community would also benefit from the creation of more developmentally appropriate, culturally sensitive direct assessments of students' motivation-related behaviours that do not rely on teachers'

reports (which may be biased by other student characteristics) or self-reports (which are not feasible with young children). To ensure that assessments of EF and motivation illuminate inequities in educational settings rather than place a burden on individual children, researchers and educators must measure and analyse students' learning environments and opportunities in tandem with their skills and behaviours **(Obradovi and Steyer, 2021)**. One way in which some of these issues has been addressed is through school interventions based on concepts of student 'character', 'grit', 'resilience' and 'growth mindset'.

3.3 .3

GROWTH MINDSET

A growth mindset of intelligence is the belief that intellectual ability can be improved through dedicated effort and learning. By contrast, a fixed mindset of intelligence is the belief that intellectual ability is set and unchangeable. Adopting a growth mindset can lead students to interpret challenges and effort as opportunities for improvement rather than markers of low fixed ability **(Dweck and Yeager, 2019)**. As students embrace growth mindset beliefs, they take more advantage of learning opportunities and become more resilient in the face of academic set backs and failure **(Blackwell, Trzesniewski and Dweck, 2007)**.

There has been considerable international interest in the use of growth mindset research to improve educational outcomes. One group of studies has measured the correlation between mindsets and outcomes, typically finding positive associations between endorsement of growth mindset and academic achievement. For example, studies of over 100,000 students in Chile **(Claro, Paunesku and Dweck, 2016)** and over 300,000 students in the USA **(Claro and Loeb, 2019)** found associations from r = .27 to .34 between growth mindset and achievement test scores

> As students embrace growth mindset beliefs, they take more advantage of learning opportunities and become more resilient in the face of academic set-backs and failure.

in reading and mathematics. Moreover, as part of the 2018 PISA assessment, the OECD surveyed over 500,000 students from 74 nations and found small positive correlations between growth mindset and achievement in 72 countries **(OECD, 2019)**. The two exceptions were China and Lebanon, which showed no association between mindset and achievement. Likewise, Li and Bates **(2019)** found no correlation between reported mindsets and grades in Chinese fifth- and sixth-grade students (N = 433), and Bahník and Vranka **(2017)** found no link between mindset and ability tests in university students from the Czech Republic (N = 5, 653), raising the possibility of cross-cultural differences in how mindsets shape academic performance.

There is also growing evidence that growth mindset interventions increase achievement for struggling students. A recent nationally representative study conducted with ninth-grade students in the USA demonstrated

that brief, online growth mindset intervention increases grades for lower-achieving students **(Yeager et al., 2019)**, replicating effects from earlier research **(Paunesku et al., 2015)**. Experimental research from Peru **(Outes-León, Sánchez, and Vakis, 2020)**, Norway **(Rege et al., 2021)** and South Africa **(Porter et al., 2020)** has also shown promising effects on outcomes like grades and enrolment in more advanced courses, though null effects were observed in a large British trial that implemented a teacher-delivered program **(Foliano et al., 2019)**. Notably, intervention effects are heterogeneous: growth mindset programs tend to improve the achievement of students who are most at risk of poorer outcomes, and those in classroom environments where newly acquired growth mindset beliefs can be put into practice **(Walton and Yeager, 2020)**.

More research is needed to understand where and why growth mindsets are most effective, and how cultural and contextual factors influence

impacts, including, for instance, how teachers' knowledge and understanding of growth mindsets may be related to teachers' effectiveness in the classroom. Research also needs to acknowledge that practical interventions to elevate students' growth mindsets, and related characteristics, are also situated in broader social and political movements.

3.3 .4

CRITICAL DISCOURSE ON 'CHARACTER' AND RELATED CATEGORIES WITH A SOCIAL AND CULTURAL VIEW

Recent policy interest in 'character education', as well as in the related concepts of 'grit', 'growth mindset' and 'resilience' can be framed within what Allen and Bull **(2018)** describe as a 'turn to character' within contemporary capitalism. In this 'turn', individualized qualities such as grit, perseverance,

resilience and 'bounce-backability' are framed as both the causes of and solutions to unequal life outcomes. As Allen and Bull **(2018)** describe, this focus on responsibilizing the individual has occurred in the context of increasing inequality within nation-states and an intensification of neoliberalism globally whereby the onus shifts from the state to the individual for managing the consequences of inequality. In sum, character education teaches people that individuals must be 'moral' (in a narrow sense of the word) because the system – free market capitalism – cannot be.

Thus, character education is seen as making increased inequality morally acceptable. Pre-dating these more recent arguments, however is a longer history of critical discussion. It has been argued that character education serves a conservative political agenda as it focuses on perpetuating the status quo rather than opening up space for change **(Boyd, 2016)**. Further critiques include its reliance on a behaviourist ontology, and

> It has been argued that character education serves a conservative political agenda as it focuses on perpetuating the status quo rather than opening up space for change.

...positive psychology legitimizes inequality by suggesting that if only people had more 'grit' they could be socially mobile – even in a context where social mobility is becoming more and more difficult.

its assumption of a Christian ontology of the human in which children are assumed to be inherently sinful and need to be taught self-control **(Kohn, 1997; Davis, 2003, p. 37; Winton, 2008; Jones, 2009, p. 39)**. Overall, character education works on the assumption that morality takes the form of supposedly universal conservative 'virtues' such as self-control, loyalty and obedience, ignoring a wider set of values that emphasize connection to others, political imagination and critical thinking **(see section 3.3; Kohn, 1997; Suissa, 2015)**.

In the United Kingdom (UK), the influence of character education on policy has been traced back to the political aspirations of the John Templeton Foundation. Also drawing on funding from the John Templeton Foundation is the 'positive psychology' movement, which mobilizes a very similar set of concepts to character education, advocating for qualities such as 'grit' and 'resilience'. While 'character' approaches tend to foreground morality, positive psychology draws on an intellectual and educational lineage around 'non-cognitive' or 'soft skills'.

However, their similarities are greater than their differences. Both posit individual character as the cause of, as well as the solution to, a wide variety of social problems as diverse as poverty, poor educational outcomes or the gender pay gap **(e.g. Gill and Orgad, 2018)**. Both obscure – or at least downplay – any social causes of such issues such as, in the UK, policies of 'austerity' whereby state services such as legal aid or support for domestic abuse are cut. Both rely on responsibilizing the individual (or at most, the family) in addressing these social problems. For example, positive psychology legitimizes inequality by suggesting that if only people had more 'grit' they could be socially mobile – even in a context where social mobility is becoming more and more difficult. It is no surprise, therefore, that those who are most strongly exhorted to develop 'character' and 'resilience' are working-class children and young people, women, people of colour and other marginalized populations.

3.3 **.5**

SUMMARY: SITUATING COGNITION, MINDSET AND CHARACTER

Psychological research on individual differences in cognition, motivation, EF, growth mindset and related approaches has begun to develop novel conceptualizations of cognitive and intellectual malleability, as well as culturally sensitive approaches which acknowledge the dynamic bidirectional interactions of individuals and environments. The scientific evidence to date has clearly established that individual differences in cognition, to a large extent, underpin individual differences in learning. The research suggests exciting applications whereby early cognitive assessments carry predictive value for identifying children at risk of struggling in school and who may need additional support to realize their academic potential. The research hints at important targets of intervention – and by extension, education – and social policies that best support children's development and learning.

Recent research on psychological individual differences, such as character education, carries political connotations. Character education, 'grit' and growth mindset approaches favour an individualistic model of education prioritizing self-improvement as a route to social mobility, while obscuring the causal and environmental factors that produce social and educational inequalities. Such approaches are politically appealing as they assume outcomes can be improved through the identification of individual differences and interventions aimed at enhancing individual capacities, but limited because they neglect the dynamic interactions of individuals with their wider environment. Our aim should be to leverage the research on psychological individual differences to understand how individual children differ and to build societies that support all children to realize their full potential.

... early cognitive assessments carry predictive value for identifying children at risk of struggling in school and who may need additional support to realize their academic potential.

3.4 Social factors and individual differences

The previous sections have outlined research in the biological and psychological sciences that have sought, in various ways, to incorporate social factors into the analysis of individual differences related to learning and educational outcomes. In this section, we engage more specifically with the question of how social

in some branches of recent social theory, the social environment is increasingly understood to get 'under the skin' to reshape biological and psychological processes, while, in a reciprocal manner, embodied actions of individuals also extend 'out of the skin' to reshape the environments they inhabit.

factors interact with biological and psychological factors. This is unfamiliar territory for social scientific approaches to education and learning, which are normally focused on external social structures and practices and their effects on students' behaviours and actions rather than on internally embodied factors.

Many social science approaches to understanding how individual differences impact on educational outcomes actively seek to disrupt individualized biological and psychological accounts of learning. Researchers contend instead that social class, gender, race and other cultural, economic and political factors remain the main determinants of educational opportunities and outcomes **(Apple, Ball and Gandin, 2010)**. Important recent work on 'intersectionality', informed by critical race theory, has begun exploring how these factors interact within and through educational institutions and policies, reproducing patterns of discrimination and exacerbating existing social, economic

and cultural advantages and disadvantages **(Tefera, Powers and Fischman, 2018)**.

However, in some branches of recent social theory, the social environment is increasingly understood to get 'under the skin' to reshape biological and psychological processes, while, in a reciprocal manner, embodied actions of individuals also extend 'out of the skin' to reshape the environments they inhabit **(Meloni, Williams and Martin, 2016)**. These emerging understandings have led to studies exploring, for example, the impact of socio-economic gradients on brain plasticity and development, as well as other biological adaptations in response to exposure to stress, trauma and socio-economic adversity and disadvantage **(Meloni et al., 2018)**. Some of the key intersections of the biological, psychological and social sciences can be found in studies of social and behavioural epigenetics and social neuroscience **(Rose, 2007)**.

Social scientific analyses of these interacting social, biological and psychological dynamics in relation to education are relatively rare. In this section, we address the bio-psycho-social dynamics of learning and education, insisting that individual differences related to learning be considered as interdependent with intersecting social and environmental factors including socio-economic gradients, (dis)advantage, race/ethnicity, gender and other sources of personal identity formation, along with the full range of social, physical and material aspects of environments in which learning takes place **(WG2-ch4)**. The first section explores the ways in which socio-economic factors may impact individual neurocognitive development, then turns to how ideas about epigenetics – how social environments affect how genes work within human lifetimes and across generations – has been applied in education, before summarizing recent social scientific research on the 'biosocial' aspects of learning.

socio-economic factors profoundly shape individual differences in cognition and affect the academic trajectories of children around the world.

SOCIO-ECONOMIC GRADIENTS AND INDIVIDUAL DIFFERENCE IN LEARNING AND BRAIN DEVELOPMENT

Nearly 12 million American children were living in poverty prior to the COVID-19 pandemic **(Children's Defense Fund, 2020)**, and more than a billion children were impacted by poverty around the world **(UNICEF, 2020)**. It is estimated that an additional 150 million children globally have fallen into poverty since the start of the pandemic **(UNICEF, 2020)**. Socio-economic disparities have for decades been linked with children's cognitive and socio-emotional development and academic achievement **(Johnson, Riis and Noble, 2016)**. These differences emerge in early childhood **(Noble et al., 2015a)**

and persist throughout the lifespan **(Moorman, Carr and Greenfield, 2018)**. Thus, socio-economic factors profoundly shape individual differences in cognition and

affect the academic trajectories of children around the world.

Research has shown that the strongest links between family

Differences in children's experience are likely at least partially responsible for these socio-economic disparities in neural and behavioural development.

socio-economic background and children's neurocognitive performance tend to cluster in certain domains, including language, memory, EF and social-emotional development **(Pace et al., 2017; Lawson, Hook and Farah, 2018; Merz, Wiltshire and Noble, 2019; WG3-ch5)**. More recently, a burgeoning field has centred on identifying socio-economic disparities in the developing brain **(Noble and Giebler, 2020)**. Indeed, research has linked socio-economic factors to certain structural and functional brain differences which underlie the aforementioned skills. For instance, socio-economic differences in cortical surface area, cortical thickness and grey matter volume have been commonly noted in frontal and temporal cortical regions **(Noble et al., 2015b; McDermott et al., 2019; Merz et al., 2020; Noble and Giebler, 2020)**, which support the development of language, EF and emotion regulation. Other work has linked family socio-economic characteristics to children's hippocampal volume, which is critical for learning and memory **(Hair et al., 2015; McDermott et al., 2019; Merz et al., 2019)**.

Differences in children's experience are likely at least partially responsible for these socio-economic disparities in neural and behavioural development. While more work is needed to fully understand the specific experiences that may account for these links, it is highly likely that parenting practices, social context and social supports for learning are mechanisms that account for these disparities. For example, cognitively and linguistically enriching experiences may serve as proximal factors that mediate neurodevelopmental differences **(Rosen et al., 2018; Merz, Wiltshire and Noble, 2019; Merz et al., 2019)**. Several recent studies have found that contingent, responsive verbal interactions between parents and children, or other forms of cognitive stimulation in the home, may mediate the links between socio-economic disparities and children's brain development **(Romeo et al., 2018a, 2018b; Rosen et al., 2018; Merz et al., 2019)**. Alternatively, exposure to chronic stress within the family has cascading effects on

Neuroplasticity describes how the brain is materially affected by learning, experience or environmental stimuli and interaction.

multiple brain and body systems, and has also been considered a likely mechanism linking socio-economic disadvantage to neurodevelopmental differences **(Dufford and Kim, 2017; Merz et al., 2019)**. Finally, although these differences in neurodevelopment are often portrayed in the literature as a 'deficit', with poverty treated as a 'scar on the brain', it is important to note that neuroplasticity theory suggests that these changes may reflect developmental adaptation to childhood adversity. Neuroplasticity describes how the brain is materially affected by learning, experience or environmental stimuli and interaction, as synaptic connections between neurons are 'wired' together, trimmed, pruned and 'rewired' across the entire lifespan **(Tovar-Moll and Lent, 2016)**. Indeed, some scholars note that children reared in poverty or other harsh environments may actually develop 'hidden talents' or enhanced skills that are optimized for high-adversity contexts **(Ellis et al., 2020)**.

The impact of socio-economic gradients on neurocognitive development and neuroplasticity highlights the importance of bringing social scientific understandings of the impact of social, economic, cultural and political factors to the study of individual differences, and in particular the complex biological and social dynamics involved in such processes. This is particularly important as recent developments in 'neurotechnologies' such as brain imaging may lead to novel conceptions of the impact of social forces on the plastic learning brain, and potentially controversial proposals for policy and practice interventions to 'improve' brain function **(Williamson, 2018)**. Such interventions, it has been proposed, might include learning software that adapts to measures of individuals' neurocognitive processes **(Royal Society, 2011)**, electrical brain stimulation to enhance cognitive performance **(Schuijer et al., 2017)** and other attempts to 'sculpt' an individual's unique learning brain **(Marope, 2016)**.

> **Research has begun exploring the possible epigenetic mechanisms that affect individual development, cognition, educational trajectories and long-term life outcomes.**

EPIGENETIC EDUCATION

Epigenetics is the process by which environments affect the molecular level of human bodies by regulating gene expression, and therefore affect phenotypical behaviours and traits without changing DNA itself. Research in epigenetics is interested in how social environments affect gene expression. Epigenetics proposes that the environment, including material and social factors, plays an important role in shaping how genes work within human lifetimes and across generations **(Pickersgill et al., 2013)**. Recently, epigenetics studies have been prominent in discussing how maternal nutrition or early-life trauma and stress affect offspring to increase the risk of disease or behavioural problems later in life. However, there is also the risk of perpetuating social discrimination based on the assumption that certain individuals might be 'epigenetically damaged' **(Müller et al., 2017)**. Such observations are significant for the social sciences as they open up questions about appropriate public policy responses to address unjust living conditions and other environmental factors that affect health and behaviour.

Research has begun exploring the possible epigenetic mechanisms that affect individual development, cognition, educational trajectories and long-term life outcomes **(Youdell, 2019)**. In terms of biological mechanisms, some ways in which epigenetics have been considered in relation to education include effects on learning and cognition, memory formation and storage **(Day and Sweatt, 2011a, 2011b)**. In particular, such studies have focused on the impact of genetic modification on the establishment of new active synaptic connections in the brain, which may be affected by social circumstances **(McEwen, 2015)**, as well as other learned behaviours **(Dias et al., 2015)**. Among the epigenetic mechanisms considered

... existing social systems and structures of schooling might themselves affect learning at the molecular genomic level, thus calling for the design of enriched environments for education...

by such work are experiences such as stress and physical exercise. Other studies have considered the epigenetic processes that might affect the development of cognitive abilities and learning within the educational environment itself, positing that existing social systems and structures of schooling might themselves affect learning at the molecular genomic level, thus calling for the design of enriched environments for education and therapy to develop healthy human brains and behaviours **(Frías-Lasserre, Villagra and Guerrero Bosagna, 2018)**.

As these examples indicate, research on epigenetics in education suggests that social, economic, cultural and other structural aspects might physically impact on the development of individual differences that then affect learning and educational outcomes. However, this body of research remains emergent rather than conclusive, and many of the conclusions are drawn from animal studies and extrapolate

to human learning and cognitive processes **(Pickersgill, 2020)**. Sociological studies showing how ideas about epigenetics have been taken up in education have begun to emerge, and show how they are often based on promises of improving interventions, which are attractive to policy-makers, rather than strong empirical evidence **(Gulson and Webb, 2018)**. Moreover, there is a tendency to overclaim the malleability and plasticity of the epigenetic body as a site of potential modification and improvement, grounded in highly normative ideals of an ideal learner and superficial accounts of environmental influence that oversimplify or gloss over social, cultural and political complexity **(Pickersgill, 2020)**.

Despite these notes of critical caution, epigenetics remains a significant potential site for productive interdisciplinary investigation between the social sciences, psychological and cognitive science, and the genomic sciences in relation to education. Future research in this

area will require highly specialized disciplinary expertise and careful discussion to identify epigenetic mechanisms, including complex social factors, that impact on the individual differences of learners and their learning outcomes **(WG2-ch4)**.

BIOSOCIAL PERSPECTIVES ON INDIVIDUAL DIFFERENCES IN LEARNING

Emerging 'biosocial' research seeks to develop transdisciplinary approaches that cut across critical social science analyses and leading developments in biology and neuroscience, such as epigenetics and neuroplasticity **(Meloni et al., 2018)**. An emerging biosocial approach to education research incorporates insights from sociology into the ways social factors shape educational trajectories, individual differences in outcomes and inequalities, with cutting-edge insights into biological processes and mechanisms **(Youdell and Lindlay, 2019)**. At the core of the new biosocial enterprise in education research is the recognition that 'learning' itself is differently conceptualized across biological, psychological, and social science disciplines, with emerging research seeking transdisciplinary accounts of the diversely distributed, intersecting, and dynamic social and biological influences on learning **(Youdell et al., 2020)**.

Biosocial theories highlight analytical approaches that bring social and biological forms of investigation into productive interdisciplinary synthesis **(Meloni et al., 2018)**. Biosocial developments are specifically found in research on learning and are premised on the notion that learning processes and educational outcomes are embedded in social contexts and physical environments, experienced through cognitive, emotional and other psychological

==In the past decade, a key development and application of more-than-human approaches to education has come through 'Common Worlds' perspectives.==

processes, and embodied in genomic and neural functioning **(Gulson and Webb, 2018)**. Biosocial approaches to learning and education seek to address longstanding concerns in the social sciences about bio-determinist accounts of the genetic inheritance of intelligence and ability which have underpinned a range of historical forms of discrimination **(Gillborn, 2016)**. Biosocial research acknowledges that learning, intelligence, attainment and so on are simultaneously biological, technical, cognitive, culturally contingent, and politically and economically shaped **(Youdell, 2017)**.

Biosocial research entails a movement away from thinking in terms of the 'application' of neuroscience or biological science in education to an approach to transdisciplinary research that is based in education and in educators' values **(Youdell et al., 2020)**. This emerging transdisciplinary approach is beginning to address questions including: What are the key

neural, biochemical, pedagogic, and relational processes involved in learning, and what is their interplay as these are produced through and exert influence on pedagogies, relationships and learning inside classrooms? How do these neural, biochemical, pedagogic, and relational processes of learning synchronize independently and in an integrated manner as a function of the learning context? **(Youdell et al., 2020) (WG2-ch1 and WG3- ch1)**.

As such, a biosocial orientation to understanding individual differences in learning demands research that is attentive to biological processes, such as those studied by neuroscientists, cognitive psychologists, and genetic scientists, and to social, environmental, pedagogic and curriculum factors of the kind analysed by social scientists **(Youdell and Lindlay, 2019)**. These new understandings of learning could enable policymakers, school leaders and educators to think in new ways about their approaches to education, as well as challenge

> ... the 'environments' that affect and shape individual differences consist of much more than categories such as family, neighbourhood, school or socio-economic status.

narrow conceptualizations of individual difference as either biologically or environmentally determined, and to redesign both the settings in which learning takes place and the pedagogies used to facilitate learning. As such, a further development related to such work is increasing attention to the 'non-human' or 'more-than-human' factors involved in shaping individual differences and learning.

MORE THAN HUMAN APPROACHES TO INDIVIDUAL DIFFERENCES

More-than-human approaches to childhood have been a constant, although growing, part of childhood and education studies since 2000 **(Prout, 2005; Horton and Kraftl, 2006; Lee and Motzkau, 2011; Kraftl, 2020; Nxumalo and Villanueva, 2020)**. Whilst varied, these approaches share a conceptual,

political and ecological commitment to examining how humans' lives are inextricably entwined with those of non-humans (e.g. animals, plants, earth systems or technologies). Scholars working in these areas have attempted to find new research methods and forms of writing that can offer insights into the workings of more-than- human 'entanglements' (mixtures of human and non-human). Those entanglements might be found in the constitution of school architectures through building technologies **(Kraftl, 2012)** or in the ways in which technologies such as mobile phones are used with/in 'natural' educational settings such as forests **(Smith and Dunkley, 2018; Land et al., 2019)**.

In the past decade, a key development and application of more-than-human approaches to education has come through 'Common Worlds' perspectives **(Taylor and Pacini-Ketchabaw, 2018)**. Common Worlds scholars have attempted to study, analyse and imagine educational spaces in

Individual differences that affect learning emerge from a wide range of molecular, psychological, social and environmental factors, and their interactions.

which a commitment to the shared worlds of humans and non-humans is foregrounded, and in which non-humans are considered actors that can bring about change in any given learning situation **(Blaise and Hamm, 2019; Haynes and Murris, 2019; Taylor, 2019; Weldemariam, 2019)**. The key finding from such studies, for example, is not that children learn from animals but rather that they learn with them – developing mutual understanding, learning how to live with other species and respond to them, and learning how to deal with death (e.g. on encountering a dead animal during a walk). Much – but not all – of this work has taken place in outdoor, early childhood settings, particularly in settler colonial contexts such as Canada and Australia. This has enabled scholar-pedagogues to support children in developing critical reflections on how (for instance) animal species introduced by settler-colonizers might be understood in complex and perhaps contradictory ways – both in terms of how humans might care for those animals, and in terms of how they articulate

their experience with forms of colonial violence **(Taylor, 2019)**.

Whilst some 'biosocial' approaches to childhood and education may be critiqued for ignoring or downplaying human differences (such as ethnicity, geographical location, sexuality or gender), researchers of more-than-human childhoods and learning have sought to remain attuned to and respectful of differentiation in all its forms. This may mean a critique of what some view as stable identity categories (like gender), but also implies sensitivity to how (for instance) gender performances might be variously and locally manifested in and through relations with non-human others **(Blaise and Rooney, 2019)**. It also means a keen attentiveness to place: to how learning is a multispecies achievement, which is focused both on the histories of land and ecological futures that can embrace and treat responsibly all forms of difference – human and non-human **(Taylor and Pacini-Ketchabaw, 2018; WG2-ch8, WG3-ch5; WG3-ch7)**. This resonates clearly with both 'deep green' ecological

> More-than-human approaches to learning, in sum, open up the category of 'individual differences' to respect and account for both the differences between all humans and non-humans and the relations between them.

thought **(e.g. Plumwood, 2002)** and efforts to create 'place-responsive pedagogies' within more critical forms of environmental education **(e.g. Mannion, Fenwick and Lynch, 2013; Spillman, 2017)**. Some of this work also resonates with indigenous land education and its attunement to decolonial and more-than-human place relations **(Tuck, Mckenzie and McCoy, 2014)**.

More-than-human approaches to learning, in sum, open up the category of 'individual differences' to respect and account for both the differences between all humans and non-humans and the relations between them. Together with social science approaches to biosocial learning, epigenetics and neuroplasticity described in the sections above, these emerging bodies of research complicate notions of individual difference and learning that emerge from primarily biological and psychological accounts. They also highlight how the 'environments' that affect and shape individual differences consist of much more than categories such as family, neighbourhood, school or socio-economic status. They draw important attention to the ways in which individual differences are profoundly shaped by complex social structures, economic and political factors, interactions with material environments and ecologies, and other living beings.

3.4 .5

SUMMARY: SOCIAL, BIOLOGICAL AND MATERIAL INTERSECTIONS OF LEARNING

Research on the molecular and psychological dimensions of individual difference and its influence on learning is increasingly attentive to the interactions of the individual with complex environments and social-structural factors such as socio-economic disparities and physical settings. As recent research

Diverse forms of research across the genomic, neural, cognitive, psychological and social sciences indicate that learning processes and educational outcomes are not reducible to either genes, brains and minds, nor to social and environmental forces.

on neurocognitive plasticity and epigenetics in relation to education has shown, there is a pressing need for studies that can identify and examine the ways in which complex social factors may impact on human bodies and lives.

At the same time, social scientific analyses foreground the social and environmental complexities of the environments and social factors that shape individual differences, personal identities, and learning processes and outcomes. Sociological research emphasizes the irreducibility of individual differences to single categories, and instead highlights how social and economic factors, the experience of race, ethnicity, gender, social class, culture and family affect how individuals come to identify themselves, and the effects of these intersecting factors on learning and education. Biosocial approaches acknowledge the interactions of embodied biological processes, environmental factors and social forces. 'More-than-

human' research also highlights the powerful role of 'non-human' beings, materials and physical settings on individual differentiation, and the implications of this recognition for the design of learning experiences and spaces.

Despite their diverse disciplinary perspectives, such studies demonstrate the need for multidimensional policy responses and practices in education, rather than interventions focused narrowly on raising outcomes by addressing single, specific influences on learning.

3.5

Key Findings

Individual differences that affect learning emerge from a wide range of molecular, psychological, social and environmental factors, and their interactions. Diverse forms of research across the genomic, neural, cognitive, psychological and social sciences indicate that learning processes and educational outcomes are not reducible to either genes, brains and minds, nor to social and environmental forces. As this chapter demonstrates, individual differences may emerge from the bidirectional interactions of intrinsic (yet malleable) biological features, such as genomic expression and brain structure, and external environmental factors, including social and economic forces, cultural influences, and physical and material environments. We offer here a series of key insights and policy recommendations from the research covered in this chapter.

Molecular genomics both increasingly specifies the complex polygenic associations between DNA and educational outcomes, and identifies the profoundly powerful role of gene–environment interactions that shape individual differences and affect learning. Across all learning outcomes, there is remarkable consistency in findings that both genetic and environmental influences matter. However, much of this research is in its early stages, and while GWAS research and PGSs appear to promise new insights into both the genetic architectures and environmental influences on individual learning

Research funding should be allocated to cutting-edge studies examining the intersections of social, biological and psychological influences on learning and educational outcomes.

outcomes, there remain significant knowledge gaps regarding the underlying mechanisms at both the biological and environmental levels. Moreover, the policy relevance of such research remains unclear at best and highly controversial at worst. In particular, claims that it may be possible to personalize education, to address individual differences in students' genetic propensities for learning, are considered by most researchers to be based on misinterpretations and over-claims from the available evidence.

Psychological accounts of cognition, mindset, character and EF are all moving in the direction of more culturally sensitive conceptualizations that acknowledge the interaction of students' psychological and cognitive processes with environments and settings, including an attention to the political ideologies embedded in such approaches to enhancing learning. Social science has begun to engage with the embodied, embrained, emotional and

cognitive dimensions of learning, eschewing environmental determinism in favour of more nuanced engagements with genomics, neuroscience and psychology, whilst also developing novel understandings of the complex intersections of social, cultural, economic, environmental and political factors that shape individual differences.

Though these various disciplinary developments cannot and should not be collapsed together, they provide a compelling set of understandings of individual difference and its influence on learning. They highlight dynamic, bidirectional interactions, intersections and entwinements of bodies, minds and environments, and caution against narrow policy or practice interventions that focus on single assumed causal factors.

3.6   [Recommendations](#)

- Policy developments focused on individual differences related to learning and educational outcomes should acknowledge that these differences are the result of dynamic interactions between biological, psychological and social processes, not the simple effect of the intrinsic qualities of the individual.

- Research funding should be allocated to cutting-edge studies examining the intersections of social, biological and psychological influences on learning and educational outcomes. This would enable new multidisciplinary research knowledge to be produced detailing the effects of social contexts, physical environments and other socio-economic, political and material influences on individual differences related to learning.

- Future research and policy development in the field of education should aim to expand notions of individual difference and learning by facilitating multidisciplinary expert working groups consisting of representatives from the social, psychological and biological sciences. These expert working groups would develop new multidisciplinary research agenda leading to novel policy-relevant findings on the intersecting social, biological and psychological factors that influence individual differences in learning and educational outcomes.

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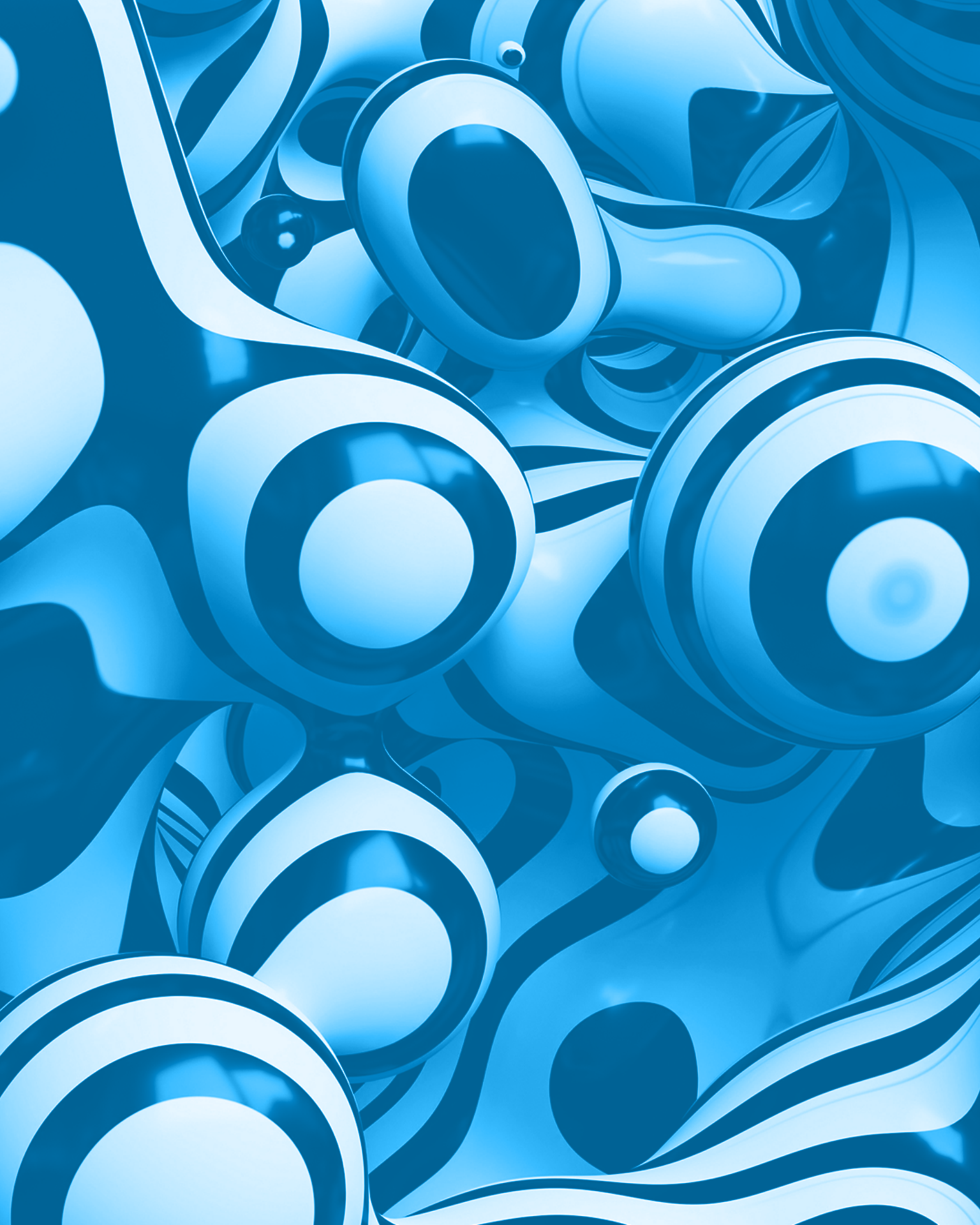
CHAPTER

4

The social and emotional
foundations of learning

This chapter should be cited as:

The goal of this chapter is to assess and discuss research and knowledge concerning the significance of social and emotional learning (SEL) in educational practices. The chapter first discusses the nature of learning, which is inherently social, relational and affective. The concept and definitions of SEL are introduced to synthesize the debate around how social and emotional experiences interact with learning processes. Then the development of socio-emotional skills across the lifespan with regards to neurobiological, social, and cultural factors is discussed, highlighting the important role of assessment in bringing a disciplined focus to SEL in schools. Applied research that describes interventions, programmes and policies geared towards promoting SEL and that can inform educational practices is then presented. The chapter concludes by recommending that SEL practices and policies should be responsive to context and culture, be informed by neurobiological development, and take into account educators' social and emotional capacities.

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4.1

Social and emotional nature of learning experiences

In this section we discuss the nature of learning, which is inherently social, relational and affective. We introduce the concept and definitions of social and emotional learning (SEL) and synthesize knowledge around how social and emotional experiences interact with the learning processes.

4.1 .1

A DEFINITION OF SOCIAL AND EMOTIONAL LEARNING

Interactions between social and

Social and emotional experiences drive and shape learning; it is impossible to remove the social and emotional aspects of human experience from the process of learning.

emotional development and learning are complex. Social and emotional experiences drive and shape learning; it is impossible to remove the social and emotional aspects of human experience from the process of learning. Social and emotional skills are also shaped by education and the learning experience. As Immordino-Yang and Damasio **(2007)** assert, 'The aspects of cognition that are recruited most heavily in education, including learning, attention, memory, decision-making, motivation, and social functioning, are both profoundly affected by emotion and in fact subsumed within the processes of emotion' **(p.7)**. Hence, how we feel affects how we learn, and can be a tool for shaping what we learn.

The social and emotional foundations of learning are linked to a series of factors that shape individual's health, well-being, decision-making and life outcomes. Learning within a social context both contributes to, and builds on, intersubjective, affective bonds. There is a substantive body of research on the affective nature

of education **(see, e.g. Ringrose and Renold, 2011; Hickey-Moody 2013a, 2013b; Dernikos et al., 2020, Franklin-Phipps, 2020; Zarabadi, 2020)**. This work argues that as learning is a form of being affected – of increasing or decreasing one's capacity to act – then affect needs to be considered as the primary vehicle of education.

Because of the expansive nature of the subject, SEL is discussed in many academic disciplines and each discipline defines SEL slightly differently. For the purposes of this chapter, we take SEL to mean 'the learner's experiences of contexts and emotions related to learning and embedded in learning'. Other related terms such as 'social and emotional skills', 'social and emotional competencies', and 'non-cognitive skills' **(Chatterjee and Duraiappah, 2020)** are popularly used in academic discussions of SEL. Although these terms are not interchangeable, here we consider them all to be subsumed under the umbrella of SEL. For example, socio-emotional skills have been previously defined by UNESCO as 'the competencies, skills and/or

attitudes [allowing] to recognise and manage emotions, develop caring and concern for others, establish positive relationships, make responsible decisions and handle challenging situations' **(Payton et al., 2000; Greenberg et al., 2003; Weisberg et al., 2015, cited in Chatterjee and Duraiappah, 2020)**. We see the development of these skills as both a goal and by-product of a healthy SEL environment.

In many parts of the world SEL improvement efforts have focused on addressing students' (and occasionally teachers') mental health. Efforts have focused also on supporting moral or 'character' development, and, at times, have evoked religious traditions in doing so. While these can be part of SEL, we argue that SEL is something broader. SEL is not merely the absence of mental health challenges, but also a space in which well-being can flourish. (The concept of well-being is certainly multidimensional, covering anything from cognitive appreciations of one's satisfaction with life up to subjective, highly affective experiences of happiness

(for a discussion of psychological, social and emotional wellbeing, **see Keyes and Waterman, 2003**. It is not merely about being morally 'good' or conforming to culturally acceptable practices and manners, but about developing the ethical and emotional ways of living a life of purpose, service and honour. Research shows that effective and sustainable SEL efforts are instructional (i.e. teaching and learning are recognized as social and emotional) and systemic (i.e. attempting to create a school climate that feels safe, supportive, affirming and engaging to diverse learners).

In addressing the systemic nature of SEL it is important to understand social and cultural dynamics instead of focusing on the individual alone. A more sociological approach can help us shed light, for example, on the value of group belonging, social class and different kinds of capital for these interconnected processes **(Bourdieu, 1986)**. Indeed, health, well-being and learning outcomes are known to widely relate to such sociological variables

SEL is not merely the absence of mental health challenges, but also a space in which well-being can flourish.

> Taking the concrete example of well-being, it has long been acknowledged that instead of considering it as an individual property, we should approach it in a systemic manner, as dependent on affective forms of learning with and from others.

(Williams, 1995). Moreover, there are marked inequalities revealed by these sociocultural analyses (Gatrell, Popay and Thomas, 2004). These inequalities are reflected early, in the quality of education and in the presence or absence of solid social and emotional foundations for learning.

Taking the concrete example of well-being, it has long been acknowledged that instead of considering it as an individual property, we should approach it in a systemic manner, as dependent on affective forms of learning with and from others (Bagdi and Vacca, 2005). Overall, well-being is intimately related, as argued here, with the opportunities available to learn and create in society. Being part of oppressed or marginalized communities diminishes one's positive appreciation of life, in part through a reduction of perceived possibilities to learn, grow and create. This is why SEL needs to address the broader ecology of which the learner is part. Tim Lomas (2015) argues, in this regard, for the importance of adopting a sociocultural,

systems perspective when it comes to SEL interventions – that is, design systems in ways that address individuals, groups, and communities, as well as cultural context, class and capital, as a whole. Research that informs well-designed SEL programmes indicates also that emotions and relationships affect how and what is learned, and thus should be foregrounded (Izard, 2002; Spinrad and Eisenberg, 2009).

4.1 .2

SOCIAL EMOTIONS IN EDUCATIONAL SETTINGS: EFFECTS ON LEARNING OF WHAT STUDENTS FEEL

The emotions that students experience in school, that is, what they feel, can affect how they perceive and perform in school. Different emotional feelings differently impact performance.

4

4.1   .2   .1

EMOTIONS IN ACADEMIC ENVIRONMENTS

In the past twenty years there has been an exponential increase in studies of affect in education. Contemporary researchers in educational psychology recognize that emotions are not merely by-products of achievement that lack instrumental relevance, but that they are critically important for cognitive performance, academic attainment, career trajectories and health, as well as institutional and national productivity **(Pekrun and Linnenbrink-Garcia, 2014; for meta-analyses, see Hembree, 1988; Tze, Daniels and Klassen, 2016; Loderer, Pekrun and Lester, 2018; Camacho-Morales et al., 2020)**. Given the importance of formal education and academic attainment across the life course, and of social interactions between peers and with teachers, these emotions occur frequently and can be very intense. This is true for positive and negative emotions. Curiosity, hope and pride, for example, can be strong drivers of learning,

as can negative emotions like anger. Studies have shown that students frequently experience negative emotions in school, including anxiety, shame, guilt and hopelessness, and when experienced chronically or intensely, these can jeopardize well-being **(Pekrun et al., 2002)**. The field of educational psychology has seen substantial growth in research on test anxiety driven by the need to deal with the affective consequences of widespread mass testing and sorting of students introduced in the decades before and after the Second World War. For example, up to 40 per cent of students are reported to experience excessive test anxiety **(Bogels et al., 2010)**.

In an educational setting, emotions are generally classified according to valence, degree of activation and object focus **(Barrett and Russell, 1998; Pekrun, 2006)**. In terms of valence, positive (i.e. pleasant) emotions are distinguished from negative (i.e. unpleasant) emotions, such as pleasant enjoyment versus unpleasant anxiety. Physiologically

Contemporary researchers in educational psychology recognize that emotions are not merely byproducts of achievement that lack instrumental relevance, but that they are critically important for cognitive performance, academic attainment, career trajectories and health, as well as institutional and national productivity.

> **Emotional competencies include abilities to identify, use and manage one's own and other persons' emotions.**

activating or arousing emotions are distinguished from deactivating emotions, such as anger versus hopelessness. In terms of object focus, Pekrun **(2006)** and others have identified distinct groups of emotions in school that are important:

1. achievement emotions relate to achievement activities and their success and failure outcomes, such as enjoyment of learning, hope for success or anxiety before an exam;

2. epistemic emotions are generated by the cognitive response to learning materials, such as surprise, curiosity and confusion;

3. topic emotions pertain to the topics presented in class, such as empathy with the characters portrayed in a novel;

4. social emotions relate to teachers and classmates, such as compassion, admiration, contempt, envy, anger or social anxiety in the classroom.

EMOTIONS AND ACADEMIC ACHIEVEMENT

Emotions profoundly influence cognitive and behavioural processes **(Barrett, 2017)**. Emotional competencies include abilities to identify, use and manage one's own and other persons' emotions (emotional intelligence) **(Matthews, Zeidner and Roberts, 2002)**. Positive emotions have been shown to promote students' interest, motivation to learn, self-regulation of learning and use of flexible and deep learning strategies **(Fredrickson, 2001)**. However, when students experience positive emotions that are irrelevant to the learning task (e.g. excitement for a date after school or pride in having helped a relative) these emotions can interfere with learning. Similarly, negative activating emotions, such as anxiety, anger and confusion, can have beneficial or adverse effects on learning. For example, anxiety can reduce intrinsic motivation (i.e. motivation that is based on interest and

Quality of classroom instruction, test taking procedures and social environments, including family and peer groups, are important environmental factors impacting students' emotions.

enjoyment) and flexible learning, but can also increase extrinsic motivation to invest effort in order to avoid failure. Negative deactivating emotions, such as hopelessness and boredom, generally exert detrimental effects on motivation and learning. Given the complexity of these effects, it would be misleading to assume that positive emotions are always beneficial and negative emotions just detrimental. Longitudinal psychological research suggests that students' emotions and their achievement are linked reciprocally over time **(e.g. Pekrun et al., 2017)**.

While emotional competencies can strongly impact academic outcomes, the opposite is also true. For students and teachers, individual appraisals related to learning, teaching and achievement in school are especially charged emotionally. Depending on the way students interpret their experiences, academic success may promote positive emotions, whereas failure may exacerbate anxiety, shame, hopelessness and boredom during

learning and test taking **(see Meece, Wigfiled and Eccles, 1990; Pekrun et al., 2017)**.

Quality of classroom instruction, test taking procedures and social environments, including family and peer groups, are important environmental factors impacting students' emotions. Related empirical evidence mainly pertains to students' test anxiety. Competition in the classroom, lack of structure in classroom instruction and lack of transparency in the demands of tests and exams are associated with elevated levels of student anxiety, likely because they reduce students' sense of control and generate expectations of failure **(Zeidner, 1998)**. As described in Pekrun's control-value theory (CVT) **(Pekrun, 2006, 2018)** and shown in empirical research **(Pekrun and Perry, 2014; Putwain et al., 2018)**, two groups of appraisals are particularly important: perceived control over achievement activities and their outcomes, and their perceived value (i.e. subjective importance). For example, enjoyment of studying is increased

when a student feels competent to master the learning material (high control) and is interested in the material (high value). Fear of failure is aroused when there is a perceived lack of control over performance in a pending exam, implying that failure is possible, combined with the perceived high importance of the exam. Other factors indirectly influence emotions. Understanding of their gender identity and its significance in their social context influences students' emotions related to school subjects such as maths and language classes. For example, female students in cultures with prevalent stereotypes about females' quantitative skills often report higher maths-related anxiety and shame and lower enjoyment than males, likely due to their lower competence beliefs

Psychological approaches to motivation provide a theory of human drive, which is important for fostering academic engagement and achievement.

in this domain **(Goetz et al., 2013)**. Research has found that while level of achievement anxiety differs between genders and countries, its relation to academic achievement is equivalent across these variables (summary of evidence) **(Pekrun, 2018)**. For example, in the 2012 cycle of the OECD Programme for International Student Assessment (PISA), students' anxiety and achievement in mathematics correlated negatively in all of the sixty-four participating countries, and all of these correlations but one were significant **(OECD, 2013)**. Beyond anxiety, teachers' enjoyment of teaching and expressed enthusiasm positively influence students' enjoyment of learning **(Frenzel et al., 2018)**. Finally, research on the effects of classroom composition has found that higher class-average achievement reduces students' positive emotions and increases their negative emotions, such as maths anxiety **(Pekrun et al., 2019)**. The findings suggest that being a member of a high-ability classroom can be detrimental to emotional well-being, likely due to a problematic culture that

rewards success relative to one's peers and reduced chances to succeed relative to others in such a classroom. These perspectives are a psychological approach to social and emotional engagement with curriculum and learning in schools and have popular and academic appeal in educational practice. Notably, other fields, including the sociology of education, criticize such approaches as not sufficiently attending to the structural, cultural factors that lead to students experiencing these emotions **(Harwood, 2003, 2006)**.

4.1	.2	.3

MOTIVATION AND SELF-DETERMINATION

Emotions can also impact learning and achievement through motivation and self-determination. Psychological approaches to motivation provide a theory of human drive, which is important for fostering academic engagement and achievement **(Collie et al., 2019)**. Motivation theories also hold promise for understanding

Self-determination theory asserts that the fulfilment of three basic psychological needs – autonomy, competence and relatedness – promotes optimal human functioning.

and promoting socio-emotional skills and their development among students. At school (and throughout life), individuals are called upon to interact with others and make sense of their emotional experiences. Motivation theories, like self-determination theory, can help to understand underlying mechanisms, which then can be useful for supporting socio-emotional skills development and other positive academic and well-being outcomes **(Collie, 2020)**.

Self-determination theory asserts that the fulfilment of three basic psychological needs – autonomy, competence and relatedness – promotes optimal human functioning **(Ryan and Deci, 2017)**. Although examined largely in relation to academic outcomes, these basic psychological needs are also relevant to SEL and its development **(Collie, 2020)**. In this context, autonomy reflects a student's sense that they have a say in how they think, act and feel in social or emotional situations and interactions, and that their choices in these socio-emotional domains reflect their genuine wishes.

Competence reflects students' sense that they are effective in their social and emotional interactions and that they are able to express their social and emotional abilities. Relatedness reflects students' experiences of positive and mutually reciprocal relationships with their teachers and peers at school. When students experience a sense of autonomy, competence and relatedness in their social and emotional interactions at school, this helps to promote autonomous motivation **(Ryan and Deci, 2017; Collie, 2020)**. Autonomous motivation involves being motivated by inherent interest and enjoyment in an activity, or by internal endorsement of the activity and its importance **(Ryan and Deci, 2017)**. Social and emotional autonomous motivation involves being motivated to act in a socially and emotionally competent way due to interest or enjoyment, or by consequences that are valued despite being external to the individual. Examples of socio-emotional autonomous motivation include a student helping out a good friend because it is enjoyable or

Self-determination theory provides an understanding of the mechanisms and manifestations that underlie SEL.

sharing a favourite toy because they would appreciate the same kindness reciprocated in future. Negative emotions can also be part of autonomous motivation. For example, anger about a societal injustice might make a student believe in the importance of studying and working to rectify that injustice. Psychological research shows that autonomously motivated students engage in behaviours that are socially and emotionally competent such as being able to freely express their feelings, causing fewer disruptions in the classroom and engaging in more defending behaviours to support victims **(Aelterman, Vansteenkiste and Haerens, 2019; Longobardi et al., 2020)**.

Self-determination theory provides an understanding of the mechanisms and manifestations that underlie SEL. The basic psychological needs and autonomous motivation reflect the mechanisms of SEL because they provide understanding about why students engage in particular behaviours at school **(Collie, 2020)**. If a child feels

confident at interacting with peers (competence), the child is more likely to be autonomously motivated to collaborate effectively with others at school, and will then enact behaviours to support this (e.g. taking turns in group work) **(Cheon, Reeve and Ntoumanis, 2018)**. Notably, the three components (basic psychological needs, motivation and behaviours) are central to students' ongoing development of socio-emotional skills and also help to lay a foundation for successful learning **(Collie, 2020)**. More precisely, the three components drive and shape learning because they influence how students manage their social and emotional experiences in school. Students who are better able to manage the varied social and emotional experiences that they encounter across a school day or week are in a better position to attain more positive academic outcomes, including academic engagement, achievement and school completion **(e.g. Doctoroff et al., 2016; Collie et al., 2019)**.

While acknowledging that by their very nature, schools are social

Interventions aimed at promoting emotion regulation have shown that emotions and achievement outcomes are often linked. Four strategies are especially important in these interventions.

institutions in which students learn socio-emotional skills in implicit and unintentional ways, educational psychologists have also fostered approaches to learning that include emotion regulation and motivation interventions (see also section 4.3.3 for a general discussion on SEL programmes and interventions). Interventions aimed at promoting emotion regulation have shown that emotions and achievement outcomes are often linked. Four strategies are especially important in these interventions **(Pekrun, 2006, 2018)**:

1. influencing emotions by selecting and modifying situations and tasks (situation-oriented regulation);

2. altering the cognitive processes prompting emotions, including (re-)directing attention and changing appraisals (attention- and appraisal-oriented regulation);

3. directly changing the component processes that are part of the emotional response (emotion-oriented regulation); and

4. improving one's competencies to enable successful learning, promoting positive emotions and reducing negative emotions (competence-oriented regulation).

Whereas targeted treatments for academic emotions other than anxiety are largely lacking, research on therapy of test anxiety has shown that combinations of cognitive (i.e. appraisal-oriented) therapy and competence-oriented skills training can be especially effective **(Zeidner, 1998; Putwain and von der Embse, 2020**

4.1 .3

SOCIAL EMOTIONS IN LEARNING CONTEXTS: EFFECTS ON LEARNING OF HOW STUDENTS FEEL

While the emotional feelings students experience can impact their academic performance, it is critical to consider not only

4

what they are feeling in school, but how they are feeling in school **(Immordino-Yang, 2015)**. That is, more than just a student's particular emotions, but the way in which they come to build and understand their emotional feelings is a critical tool shaping their learning and evidence of the learning itself. Educators have a powerful opportunity to create productive SEL when they scaffold young people in understanding how they feel, that is, guiding the way they make meaning of their experiences. For more than a century, expert educators and developmental scholars like Montessori and Vygotsky have noted that play is a critical way in which young people come to make sense of their world and their role within it. As educators and therapists have long observed, there is a reciprocal relationship between how people understand their experiences and their well-being, which guides their learning and future action.

==Play is a multifaceted concept that can be thought of as a disposition, attitude or activity that is voluntary, pleasurable and intrinsically motivating==

| **4.1** | **.3** | **.1** |

PLAY AND INFORMAL LEARNING

Play is a multi-faceted concept that can be thought of as a disposition, attitude or activity that is voluntary, pleasurable and intrinsically motivating **(Fink, Mareva and Gibson, 2020)**. Many definitions emphasize that play is undertaken for its own sake, rather than to meet external demands or immediate rewards or needs **(Nathan and Pellegrini, 2012)**. Play is often positioned in contrast to 'work' or serious activities, but it is closely linked to learning and development in childhood and beyond. Free-play gives children opportunities to build independence and to cope with new emotions or unexpected situations **(Brussoni et al., 2015; Rao and Gibson, 2019)**, while guided play, that is, playful learning opportunities supported and scaffolded by skilled adults, can support classroom based learning **(Weisberg et al., 2016)**. Play has been associated with many different facets of learning such as language

Informal play is a primary and powerful means through which to teach children and to stimulate creative thinking, yet some forms of play can also be used as a way to 'discipline' children into a particular ideal of thinking and doing later in life ...

ability, social and emotional regulation, mathematics skills, and causal reasoning **(Whitebread et al., 2009; Buchsbaum et al., 2012; Orr and Geva, 2015; Toseeb et al., 2020)**. Taking language development as an example, it is well-established that the symbolic meaning-making involved in pretend play is closely related to the symbolic, meta-representation capacities needed for language acquisition **(Quinn, Donnelly and Kidd, 2018)**. Recent research has demonstrated that early playful experiences with parents or caregivers (e.g. singing, playing pretend) contribute directly to measures of a child's social and academic school readiness, and in middle childhood (seven-nine), competencies in social play with peers predict outcomes on standardized literacy tests. Importantly, these effects of play upon literacy outcomes are present even when effects of family economic circumstances, language ability, phonological skills and general IQ have been accounted for **(Gibson et al., 2020)**. These examples illustrate that play makes the most of the social and

emotional nature of learning and it is linked with both academic achievement and socioeconomic status. Through play, learning can be a motivating, joyful and social experience. Educators do not have to choose between 'serious work' and 'play' when considering what is best for supporting student learning.

Informal play is a primary and powerful means through which to teach children and to stimulate creative thinking, yet some forms of play can also be used as a way to 'discipline' children into a particular ideal of thinking and doing later in life. Play and informal learning offer ways to know and shape the world. As play scholar Sutton-Smith observed: 'All forms of play are transformations of four basic modes by which people know the world: copying, analysis, prediction, and synthesis' **(Sutton-Smith, 1970, p. 1)**. In the case of informal learning, play is not only a transformation of knowing the world, but also of producing worlds **(Sicart, 2014, 2018)** through practices like experimenting,

testing and creativity in a less controlled environment. Play is thus a powerful way to informally learn about the world (epistemology) and produce and experiment with worlds and worldviews (ontology).

Play is often part of informal educational practices, especially in less strict educational settings or non-educational settings. Through free and creative practices such as sandbox play, role-playing, clay modelling, counting games, singing or mind-play (daydreaming, c.f.) **(Sutton-Smith, 2001)** diverse skills including musicality, cognitive skills, social performativity and physical boundaries (e.g. playfighting), but also an understanding of social realities and structures (e.g. gender roles/hierarchy), are developed. Yet, when we think of play as an activity for informal learning, we often associate this with children who learn through free play and associate it less with young adults. Play does not leave education at a certain age, but instead seems to become more formalized.

==...promoting healthy SEL to enable creative exploration requires creating a school culture and climate that values nurturing supportive relationships==

4.1	.3	.2

CREATIVITY

Research from sociocultural approaches to creative learning **(Burnard, Grainger and Craft, 2006; Craft et al., 2012; Glaveanu et al., 2019)** repeatedly shows that establishing healthy and secure relations with(in) one's environment has a direct impact on learning processes and, in perspective, contributes to the learner's well-being **(Burnard and Dragovic, 2014; Fenyvesi et al., 2021)**. It is this broad feeling of safety and trust that ultimately helps learners reach out to others and engage in curious, creative and playful explorations of the world **(Winnicott, 1971)**. Trust is a key prerequisite for well-being, creativity and learning **(Sousa and Lamas, 2012)** as it helps generate a climate that encourages learners – and teachers – to take risks and to value failures. Whether a child, a headteacher, a classroom teacher, a teaching assistant, part of the support staff team or a parent/carer, being a member of a community that focuses on

Creative approaches to learning engage learners emotionally through aligning learning experiences with learner's interests.

creative environments, ecologies and practices, and is building a collective means of co-authoring and sculpting new and diverse creativities, will discern more clearly new ways of nurturing learners' and teachers' well-being **(Burnard and Loughrey, 2021)**. To this end, promoting healthy SEL to enable creative exploration requires creating a school culture and climate that values nurturing supportive relationships.

Creative approaches to learning engage learners emotionally through aligning learning experiences with learner's interests **(Hickey-Moody, 2013a, 2019, 2021)**. These approaches often embed learning in larger activities, which can be informal and not appropriate for formal assessment. One of the most valuable aspects of creativity is that it runs through both arts and sciences and it is the primary way that children learn content in these discipline areas **(O'Donnell, 2015)**. Foregrounding creativity in schools can help foster

SEL because the open-ended, exploratory nature of creativity mirrors the open-ended process by which students come to build meaning around their emotional feelings. Creative, divergent tasks afford students opportunities to solve real problems and arrive at new possibilities, rather than converge on 'correct answers'. This is valuable preparation for the professional and personal challenges they will face outside school, where there is rarely a correct answer.

Theory and empirical evidence within the field of the psychology of education have long connected positive mood and creativity (for a meta-analysis see **(Baas, De Dreu and Nijstad, 2008)**, while recent studies have explored a wider range of emotions, including sympathy **(Yang and Yang, 2016)**, nostalgia **(van Tilburg, Sedikides and Wildschut, 2015)** and anxiety **(Leung et al., 2014)**. In many instances, creativity implies the social and extends beyond formal educational contexts.

4.2

Social and emotional learning throughout the lifespan

Humans are born with an innate capacity for forming social and emotional connections; indeed our very survival is dependent upon forming such connections. We are evolutionarily, biologically social, cultural creatures **(Rogoff, 2003)**. These social and emotional connections are necessary not only for basic survival, but also for learning and higher-order cognition. Learning is either facilitated or hindered by the social and emotional experiences of the learner. Therefore, an individual's emotional and social development is as important as the individual's cognitive and biological development, and the two develop in tandem. It

Humans are born with an innate capacity for forming social and emotional connections; indeed our very survival is dependent upon forming such connections

is imperative to attend to the socio-emotional dynamics of young people's neurobiological and psychosocial development and to provide experiences to support intellectual and personal learning, growth and development **(Immordino-Yang, Darling-Hammond and Krone, 2019)**. It is pivotal that education systems are able to address and contribute to this aspect of human experience **(see WG1-ch5)**. In this way, an important part of SEL involves creating a climate that is safe, supportive and engaging for youth.

As per the introduction, SEL can be broadly defined as the process of acquiring the competencies, skills and/or attitudes to recognize and manage emotions, develop caring and concern for others, establish positive relationships, make responsible decisions and handle challenging situations **(Payton et al., 2000; Greenberg et al., 2003; Weissberg et al., 2015, cited in Chatterjee and Duraiappah, 2020)**. Here, we emphasize the relevance of three sets of interrelated skills that are central for SEL: cognitive, emotional and interpersonal skills.

The cognitive component broadly refers to self-regulatory abilities and includes aspects such as being able to focus and pay attention, set goals, plan and organize, persevere and solve problems. The emotional component refers to capacities for processing emotional feelings, including recognizing and managing one's emotions, understanding the emotions of others, demonstrating empathy and coping with frustration and stress. Finally, the interpersonal component refers to social-interactive abilities and includes being able to accept the perspectives of others, navigate social situations, cooperate with others and demonstrate respect toward others. SEL involves developing self-awareness, self-regulation, social awareness, relationship skills and responsible decision-making **(CASEL, 2019)**.

This section describes the development of SEL from birth through to young adulthood and highlights the important role of assessment in bringing a disciplined focus to SEL in schools.

4.2 .1

DEVELOPMENT OF SOCIO-EMOTIONAL SKILLS

The development of SEL across a lifespan is non-linear because it occurs in dynamic, culturally variable contexts, and involves engaging with the challenges of everyday life **(Fischer and Bidell, 2006)**. That is, young people develop skills, dispositions and understandings that are appropriate and useful for the complex web of situations and relationships they experience. In turn, these skills shape, and are shaped by, their biological dispositions. Individuals may progress and regress, build and rebuild, as they develop socio-emotional skills and dispositions in their contexts, in part because they must draw together many basic social and intellectual skills. Further, patterns of development vary across individuals, and that variability sheds light on who

a person is becoming **(Fischer and Bidell, 2006)**. This section discusses a pattern of how SEL can be considered across years of development.

In this section we focus on infancy, early childhood and adolescence, since these represent the periods of most substantial socio-emotional growth. However, socio-emotional skills are important and develop across the entire lifespan. Although not our focus here we note that during middle childhood, children develop a greater sense of autonomy and can develop meaningful, reciprocal friendships. Starting in adolescence and continuing into young adulthood, people refine their sense of purpose in life and determine how they will contribute to their family, community and society.

4.2 .1 .1

SEL AND BRAIN DEVELOPMENT

Not only do we grow up in a dynamic, interconnected

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Socio-emotional interactions involve cognitive processes and bodily, physiological changes.

environment, but also brain development is a dynamic, non-linear process of building and rebuilding connections. From a psycho-social and neurobiological perspective, two especially important periods in socio-emotional development are the period from birth through childhood and the period of adolescence **(see also WG1-ch3)**. During these periods, the brain is maximally sensitive to social interactions in the environment **(Chatterjee and Duraiappah, 2020)**. Brain maturation and cognitive, socio-emotional development run in parallel and constantly influence each other. As such, it is vital to consider strategies that support SEL in accordance with the neurodevelopmental and learning processes in these periods.

Patterns of brain development are the result of the interaction between genetics, epigenetics (environmental effects on gene expression), environmental factors and the social and emotional experiences of the individual **(Black et al., 2017; Britto et al., 2017)**. This highlights the close relationship between the emotional and cognitive dimensions, which is so necessary for the development of self and emotional regulation **(Changeux and Dehaene, 1989; Pessoa, 2008; Robson, Allen and Howard, 2020)**. At the same time, neurodevelopmental processes and psychological skills and dispositions are influenced by interactions, relationships, the environment, opportunities and emotional experiences.

Socio-emotional interactions involve cognitive processes and bodily, physiological changes. Various socio-emotional skills and dispositions that emerge in the first two decades of life, develop alongside the maturation of the brain. Socio-emotional skills do not arise and develop in isolation, but rather establish a bidirectional relationship with other skills and change over time in response to the maturation of those skills and dispositions and the reorganization of neural circuits.

| 4.2 | .1 | .2 |

SEL FROM BIRTH THROUGH LATE CHILDHOOD

4

CHAPTER

Emerging science highlights immense brain architecture development in the first years of life and the lasting impact of both positive experiences - such as healthy, reciprocal relationships - or adverse events - such as toxic stress in early childhood – on an individual's life.

Emerging science highlights immense brain architecture development in the first years of life and the lasting impact of both positive experiences – such as healthy, reciprocal relationships – or adverse events – such as toxic stress in early childhood – on an individual's life **(National Scientific Council on the Developing Child, 2007; Fox, Levitt and Nelson, 2010; Shonkoff et al., 2012; Nelson, 2014)**. The construction of brain architecture in the first years of life is dramatic and complex because the brain gradually shapes and adapts itself so that it can learn and respond to the challenges of the environment. At this stage, the brain is highly plastic **(see WG3-ch5)**. This is why social relationships and interactions, which are affected by emotional feelings, represent an important factor in the process of brain development **(Moore, 2006; Garner et al., 2012; National Scientific Council on the Developing Child, 2012; Vela, 2014; Immordino-Yang and Knecht, 2020)**.

Although the brains of newborns are immature, they possess a set of core cognitive, social and emotional processes, allowing them to build a progressive understanding of the world, and of the mental states and emotions of people that surround them. As a child's brain continues to develop and engage with their surroundings, the different regions of the brain, such as the regions related to visual perception, movements, cognition and language, become increasingly sophisticated **(Fischer et al., 1993; Gopnik, Meltzoff and Kuhl, 2000; Kuhl, 2010; Diamond and Lee, 2011; Diamond, 2013)** as those regions provide basic inputs for the construction of socio-emotional skills. Through initial interactions with their caregivers, these connections allow the first socio-emotional skills to be built. For example, babies rapidly learn to smile in response to affectionate relationships, or cry to express discomfort or annoyance. In this sense, the experiences of the first months of life lay the foundations for a long process of socio-emotional development, thus making high-quality relationships and interactions with adults very important **(Sameroff, 1975; Howes, 1999; National Scientific Council on the Developing Child, 2004)**. As another

Although the brains of newborns are immature, they possess a set of core cognitive, social and emotional processes, allowing them to build a progressive understanding of the world, and of the mental states and emotions of people that surround them.

example, self-awareness (i.e. the ability of a child to accurately recognize their emotions and thoughts, and understand how these influence their behaviour) is constructed in interaction with cognitive, motor, social, emotional, sensory and linguistic processes. That is, a child must observe, attend to, identify and verbalize expressions of emotional feelings in order to have self-awareness. Experiences such as positive and effective emotional communication **(Tronick, 1989)**, situations that generate emotional stability **(Howes and Smith, 1995)**, a network of secure affections and attachments built between parents, educators and children **(Pianta and Steinberg, 1992; Howes, 1999)** and loving and sensitive care **(*The Lancet, 2016*)** are all critical to a child's brain development and their SEL. The role of adult affection in early childhood is essential for the child's brain development, since the affective bond allows the baby to adapt to the environment and develop autonomy and self-confidence **(see also WG3-ch5).**

As neurodevelopment advances in early childhood, different socio-emotional competencies also advance. By three years of age, children have a significant emotional repertoire. This runs in parallel with the maturation of the neural circuits in specific areas of the brain and the communication between different networks. During early childhood, sensorimotor and language areas of the brain become more efficient and integrated, allowing children to develop language, social communication, joint attention, motor coordination, capacities for feeling, expressing and perceiving emotions, and a more complex understanding of their environment. Under the slow protracted development of frontal cortices, children learn to deal with conflicting information by starting to develop the ability to control their behaviours and thoughts (inhibitory control) and the ability to control immediate impulses and desires to achieve a goal in the future (self-control) **(Diamond, 2013).** Children begin to combine emotional, social and cognitive skills, such as

using language to express their emotional states, ability to 'read' emotions in themselves and in other people, inferences to try to understand emotions and thoughts, thinking skills to project the behaviours of others, and inhibitory control to improve their ability to self-regulate. Research has shown that early social relationships help set the stage for later socio-emotional development, including the development of identity and self-

understanding and the capacity to participate in healthy relationships **(Ainsworth, 1989; Vaughn, Bost and van IJzendoorn, 2008; Bronwell, 2016).**

During middle-late childhood, cognitive, behavioural and socio-emotional development are driven and influenced by the maturation of associative regions of the brain involved in bringing together information from different senses. By combining and associating different types

During middle-late childhood, cognitive, behavioural and socio-emotional development are driven and influenced by the maturation of associative regions of the brain involved in bringing together information from different senses.

of information, children build a set of more abstract and formal representations about the physical, cognitive and socio-emotional world and about themselves. In addition, social, emotional and cognitive development are closely related throughout childhood. For instance, inhibitory control plays an important role in the development of socio-emotional abilities, including emotional regulation **(Carlson and Wang, 2007)**.

Respecting the evolutionary process of socio-emotional development implies the organization of specific actions for children's stages of development, as well as their contextualization based on the environment in which they are immersed. In this sense, programmes for learning and socio-emotional development gain greater weight and achieve better results when they are related to the neurodevelopmental process, since socio-emotional skills are intertwined with the skills of the other dimensions and are stimulated in a contextualized way, that is both dynamic and evolutionary.

4.2	.1	.3

SEL AND ADOLESCENCE: PSYCHOSOCIAL DEVELOPMENT

Adolescence (the developmental period from the onset of puberty to establishment in adulthood) is a critical period in which many of the factors that contribute to lifelong well-being are, or are not, acquired or solidified **(Ross et al., 2020; WG3-ch5)**. It is a period of intense biological, cognitive and psychosocial development. During the course of adolescence, people can develop stronger reasoning skills, and logical and moral thinking, as well as become more capable of abstract thinking and making rational judgements **(Crone and Dahl, 2012; Gibbons, 2019; Gotlieb, Yang and Immordino-Yang, forthcoming)**, all of which have a profound influence on their health and well-being and their learning experiences. Adolescents have improved abstract thinking capabilities **(Dumontheil, 2014; Gotlieb, Yang and Immordino-Yang, 2021, forthcoming)**. They more frequently show emotions that are more intense and volatile than

==Having social support and having a productive network of friends, family and significant others contribute to positive development and learning experiences, especially among adolescents.==

in adulthood. Additionally, these emotions differ from emotions observed in childhood **(Guyer, Silk and Nelson, 2016).**

The biological, brain and social changes that take place during the years of adolescence make youth increasingly focused on finding their place. Having social support and having a productive network of friends, family and significant others contribute to positive development and learning experiences, especially among adolescents. Adolescents seek to belong in institutional, familial and community settings. They become more attuned to their social status, both as individuals and as members of social groups defined by factors such as gender, ethnicity, religion, socio-economic resources and sexual orientation. At the same time, adolescents increasingly want to make contributions to their social worlds in ways small and large **(Fuligni, 2019; Crone and Fuligni, 2020)**. Whether by helping friends and family or having an impact on their communities and nations, youth have a strong

desire to give support, resources and input to other people and organizations in their lives. Being able to make meaningful contributions – helping friends, family and community members – predicts better psychological and physical health among youth **(Schacter and Margolin, 2018; Schreier et al., 2013; van Goethem et al., 2014)**. Many marginalized adolescents wish to use their emergent understanding of their place in the social hierarchy and experiences of discrimination to try to find ways to help their communities **(Sumner, Burrow and Hill, 2018)**. But evidence suggests notable disparities in adolescents' opportunities to make contributions to their social worlds **(Fuligni, 2020)**. Societies should take a close look at how they can provide greater opportunities to make contributions to their communities to counter the many insidious effects on adolescent development presented by social marginalization and to capitalize on these young people's many assets.

Development during this period depends on both

For many young people, adolescence presents rich opportunities that promote healthy development. But for others, particularly those from marginalized groups, the adolescent period presents a period of challenge and vulnerability.

individual characteristics and the environments in which adolescents live, learn, play and work **(Blum et al., 2012)**. These external influences, which differ among cultures and societies, and which can serve as risk or protective factors, include social values and norms and the changing roles, responsibilities, relationships and expectations of this period of life **(Viner et al., 2012; Patton et al., 2016)**. These changes affect adolescents in their immediate environment of family, school and community but reflect a range of wider societal changes, including increasing urbanization, globalization and access to digital media and social networks **(Moreno, Standiford and Cody, 2018)**. Age, gender, socio-economic status, ethnicity and urbanicity, among other factors, contribute to adolescents' socio-emotional experiences, and thus their learning. For example, gender norms have impacts at a structural level, reflected in inequalities and restrictions in jobs and education; at a more proximal level in terms of family decisions about allocation of resources and the relative importance of education

for males and females; and at an individual level, influencing adolescents' expectations, what they feel they should or should not do, what they judge to be 'right' and 'wrong' **(Viner et al., 2012; Weber et al., 2019)**.

For many young people, adolescence presents rich opportunities that promote healthy development. But for others, particularly those from marginalized groups, the adolescent period presents a period of challenge and vulnerability. SEL initiatives need to support vulnerable adolescents in particular: those living with disabilities or chronic illnesses; those exploited and abused; those stigmatized and marginalized because of sexual orientation or ethnicity; those living in remote areas or caught up in social disruption from natural disasters or armed conflicts; those who are institutionalized; those exposed to domestic violence or substance abuse in the family; and those without access to education, health services or social protection **(Azzopardi et al., 2019)**.

On average, adolescents show greater activation in the amygdala in response to faces portraying negative emotions compared to children and adults.

4.2 **.1** **.4**

SEL AND ADOLESCENCE: NEUROBIOLOGICAL DEVELOPMENT

In recent decades, it has become clear that the adolescent brain goes through significant changes in terms of function and structure **(Giedd et al., 1999; Mills et al., 2016)**. Current models of adolescent social brain development characterize adolescence by increasing neural sensitivity to rewards as assessed by striatum activation that increases with age and peaks around mid-adolescence, as well as heightened sensitivity to peer influences **(Steinberg, 2014; Schreuders et al., 2018)**. The limbic system involved in the emotional response to reward, and more generally in the feeling of pleasure (involving a particular neurotransmitter, dopamine), matures more quickly than the system in the prefrontal cortex that regulates the activity of the limbic system **(Casey, 2015)**. As a result, socio-emotional processing becomes intensified in adolescence, as described in the preceding section **(Blakemore, 2008;** **Hare et al., 2008; Steinberg, 2014)**.

Pubertal hormones (testosterone and estradiol) drive brain maturation during adolescence **(Peper and Dahl, 2013)**. Specifically, the heightened sensitivity of the subcortical brain regions is related to increasing levels of the gonadal hormones associated with the onset of puberty **(Nelson et al., 2005; Goddings et al., 2014; Wierenga et al., 2018)**. Specifically, these brain regions seem to influence social and affective processes through brain maturation at the structural and functional levels. For instance, sexual hormones modulate activity within the striatum during reward processing, within the amygdala and striatum in response to emotional stimuli, and within the anterior medial prefrontal cortex and temporal-parietal junction in social reasoning tasks. While these changes create an opportunity for young people to experience more complex emotional feelings than previously, they also create a vulnerability to emotional and mental health disorders **(Steinberg, 2014)**.

On average, adolescents show greater activation in the amygdala in response to faces portraying negative emotions compared to children and adults **(Guyer et al., 2008; Hare et al., 2008)**. Emotional reactivity is also thought to reflect maturational changes in subcortical regions that are sensitive to associated pubertal hormonal changes **(Crone and Dahl, 2012; Goddings et al., 2014; Guyer, Silk and Nelson, 2016)**. This heightened emotional reactivity renders emotional and attentional regulation more difficult in adolescence **(Ahmed, Bittencourt-Hewitt and Sebastain, 2015)**. Emotional regulation in adulthood relies on top-down regulation of the amygdala by the ventromedial prefrontal cortex and this only emerges during adolescence **(Tottenham and Gabard-Durnam, 2017)**. While parents can support emotional regulation in children, this becomes more challenging during adolescence **(Tottenham, 2015)**. This can, in part, be explained because the impetus for adolescents' emotions are more abstract than the concrete causes of emotional experiences in children.

In recent decades, neuroscientific studies have identified several brain regions that are involved in social cognition, including processes related to the theory of mind, perspective-taking and mentalizing, referred to as the 'social brain network' **(Blakemore, 2008)**. These processes, along with processes of affect and self-regulation, are central to successfully navigating the social environment **(Andrews, Foulkes and Blakemore, 2020)**. Theory of mind and perspective-taking abilities develop rapidly through preschool years but follow a protracted development through late childhood and into mid-adolescence, paralleling the protracted maturation observed in the 'social brain network' **(Adolphs, 2009)**. Moreover, in order to understand the origins of schooling success and failure, as well as to promote (academic) flourishing, it is vital to understand the role that social functioning plays in shaping learning **(Blakemore, 2010)**.

Key to the success of SEL programmes is that they begin early in development, are contextualized in the environment, and are integrated with the other dimensions of development.

| 4.2 | .1 | .5 |

INDIVIDUAL DIFFERENCES

While research has tended to focus on studying average developmental trends, there is evidence of significant individual differences in brain development, behaviour and mental processing **(Foulkes and Blakemore, 2018; see also WG3-ch3)**. When we average across individuals, we may miss important variability that can exist at the margins. It is important to study individual differences because an average trend may not actually be descriptive of any individual being averaged given the multiple dimensions of socio-emotional skills on which people can vary **(Rose, 2016)**. Individual variability can also interact with variations in socio-emotional experiences that arise due to cultural influences **(Immordino-Yang and Gotlieb, 2017)**. For example, while cross-cultural studies have suggested there are consistent global patterns in adolescent development **(Steinberg, Icenogle and Shulman, 2018)**, there are also differences with regards to risk-

taking **(Duell et al., 2018)**. Cultural differences may, in part, be due to differences in national wealth, access to education and legal age limits for driving or drinking alcohol **(WHO, 2001; Viner et al., 2012; see also WG2-ch3 and WG2-ch4)**. Another source of individual differences is socio-economic status, which has been found to associate with a wide range of brain and cognitive functions and behaviours, including in the socio-emotional domain during adolescence **(Foulkes and Blakemore, 2018)**.

| 4.2 | .2 |

EXPERIENCES, ENVIRONMENTS AND SOCIAL RELATIONSHIPS SHAPE SEL

Key to the success of SEL programmes is that they begin early in development, are contextualized in the

> The majority of learning takes place in a highly social context, with parents at home during early childhood and later on surrounded by peers and friends in the classroom.

environment, and are integrated with the other dimensions of development. Social, cultural, temporal and physical contexts affect the experience of SEL. One powerful force that profoundly affects SEL across contexts is family and community social and economic status. SEL develops through interactions and relations with parents and siblings, which are in turn affected by the social environment. In addition to a child's home situation, schools and communities play an important role in SEL. Therefore, they have a responsibility in developing the socio-emotional skills of youth. Below, we discuss the effect of peer relations and teacher–student interactions on SEL **(see also WG1-ch5)**. We offer these as two examples of the broader idea, in the tradition of Bronfenbrenner, that context and relationships dynamically shape SEL. Further, research from across disciplines has converged to suggest that individuals' interpretations, both conscious and unconscious, of these relationships also powerfully colours their experience and behaviour.

4.2	.2	.1

SEL AND PEER RELATIONSHIPS

The majority of learning takes place in a highly social context, with parents at home during early childhood and later on surrounded by peers and friends in the classroom. Even when not surrounded by others, learning is very social in nature in that it is organized by, and understood as, useful for navigating the rules and tools of society. Once a child attends school, the two most salient developmental tasks they face are academic achievement and formation of successful peer relationships, each of which is dependent upon cognitive and social development. Adolescents are expected to learn, succeed in school and make decisions related to their future. Moreover, adolescence is a phase of re-orientation from parents to peers: whereas children spend the majority of their time with their parents, adolescents spend increasingly more time with their peers **(Larson, 1989)** and peers emerge as significant attachment

For many children, playful interactions with their peers during leisure time and school are self-evident.

figures **(Raja, McGee and Stanton, 1992)**. Research on reinforcement learning has shown that children imitate the choices of their peers more than those of adults **(Rodriguez Buritica et al., 2016)**, providing evidence that peers influence learning. Influence of peers on learning might be exacerbated in the context of friendships, where support and security provided by friends can have stronger effects **(Barry and Wentzel, 2006)**. For example, relationship closeness with classmates was shown to promote learning in adolescence **(Hartl et al., 2015)**. In addition, it has been shown that brain activity is modulated by peer presence in adolescence **(Chein et al., 2011; Somerville, 2013; Van Hoorn et al., 2016)** and can be diminished when students are excluded or bullied by peers. The social context of peers is likely to have strong motivational effects on learning for adolescents. Below we discuss communication impairments as an example of how difficulties in forming peer relations can negatively impact SEL. Notably, many students experience difficulty with forming peer relations, for a variety of different reasons, ranging from challenges associated with attention deficit disorders to barriers related to language or immigration status.

For many children, playful interactions with their peers during leisure time and school are self-evident. However, some children do not experience peer relations as pleasant: breaks at school are a source of stress. Almost one in ten children has a communication impairment, for example caused by hearing loss, autism spectrum disorder or a developmental language disorder. Classrooms are often noisy and playgrounds are even worse when no precautions are taken. This might cause children with hearing loss to miss out on what has been said. When the rules of a game are suddenly changed by one of the children, how would they know? Jokes are not understood, so why is everyone laughing? Children with autism spectrum disorder or developmental language disorder might become confused in such situations, which prohibits them

Empathy is an emotion that shows compassion for another person's distress and is crucial for bonding and forming meaningful relationships.

from participating fully in their peer group. In the best case scenario, they might have one friend in the class or they are accepted, yet always on the fringes, never the one to initiate a new game or take the lead. In worse case scenarios – sadly encountered often by most children with communication impairments – they are either neglected and play no role at all, or they are teased and bullied by their peers **(Maïano et al., 2016)**. So how does this social ostracism affect children's SEL?

Research examining emotional and social functioning shows deviant patterns in many aspects for children with communication impairments. Children with communication impairments often have more difficulties recognizing other people's emotional expressions, have more difficulties with understanding more socially and cognitive complex emotions such as jealousy, shame or guilt, and very often have difficulties understanding the causes of other people's emotions **(Begeer et al., 2008; Rieffe, 2012)**. This also negatively impacts their empathic

responses towards others **(Rieffe et al., 2016)**. Empathy is an emotion that shows compassion for another person's distress and is crucial for bonding and forming meaningful relationships **(Hofmann, 1987)**. Feeling for another person is thought to be an innate capacity; if one baby starts to cry, others will soon follow. Yet, soon toddlers learn that this distress they experience is not their own, but the contagious reaction to another child's distress. Indeed, many studies show no differences in affective reactions in children with and without communication impairments. Yet when children grow older, feeling for another person's distress is no longer sufficient. It is also important to have 'empathic understanding', that is, to understand why the other person is upset so the child can support the upset child in a way that is indeed comforting. Unfortunately, taking another's perspective, thus also empathic understanding, is severely hampered in many children with communication impairment **(Rieffe et al., 2016)**. Therefore, it is perhaps not surprising that

Researchers are beginning to recognize the importance of teachers' own socio-emotional competence (i.e. high SEL) in implementing student SEL effectively and promoting a healthy classroom climate.

children with communication impairment have more problems socially, including difficulty in forming friendships, and report more feelings of loneliness **(Rieffe et al., 2018; Sedgewick, Hill and Pellicano, 2019; van den Bedem et al., 2018)**. In addition, these impairments have a negative impact on their mental health over time **(Li et al., 2020)**. Note however, in the studies mentioned above, children with hearing loss, for example, have no additional diagnoses or disabilities besides their hearing loss. In other words, their cognitive capacities have similar variation as in the population with intact hearing and thus cannot account for their social and emotional impairments. Language levels also do not explain these impairments **(Netten et al., 2018)**. This suggests that children with hearing loss have the same potential to develop emotionally and socially in line with their hearing peers, if they would have sufficient access to their social environment and equal opportunities for social learning. Therefore, actions for prevention of these difficulties in children with communication

impairments should focus on how the environment can be adapted for the enhancement of their social inclusion.

4.2 .2 .2

SEL AND TEACHERS

Teachers are the primary force in school shaping students' SEL. Researchers are beginning to recognize the importance of teachers' own socio-emotional competence (i.e. high SEL) in implementing student SEL effectively and promoting a healthy classroom climate **(Jennings and Greenberg, 2009; Domitrovich et al., 2016)**. Teachers' socio-emotional skills are often examined within the context of their proficiency in supporting student SEL development. The more socio-emotional skills a teacher has, the more capable they are in supporting a student's SEL **(Jennings and Greenberg, 2009; Jones, Bouffard and Weissbourd, 2013)**. Further, the implementation of SEL also encourages the development of teachers' own

> Teachers' SEL follows the same dynamic process of cognitive development as any learner – but with one significant addition – the relationship to a student.

socio-emotional skills, improving their relationships with colleagues and students **(Martinsone and Vilcina, 2017b; Martinsone, Ferreira and Talic, 2020)**. Recently, there have been calls to better understand the factors that constitute and contribute to teachers' socio-emotional skills **(Jennings, Roberts and Jeon, 2018; Aldrup et al., 2020)**. These approaches commonly focus on negative impacts on teacher well-being and occupational health (e.g. depression, anxiety and stress) **(Jeon, Buettner and Grant, 2018)**. Less research focuses on the role of teachers' own socio-emotional competence **(Jennings et al., 2019)** and its connection to teachers' personal socio-emotional development **(Rodriguez et al., 2020)**. It is essential to consider the teacher as a learner working towards socio-emotional competence and the developmental trajectory of the teacher SEL needed to support students.

Before we explore the role of teachers' SEL in supporting student learning, we must first recognize teachers as learners in need of socio-emotional development. A growing body of literature considers the complexities of teachers' SEL **(Chen, Yin and Frenzel, 2020)**. Teachers' SEL follows the same dynamic process of cognitive development as any learner – but with one significant addition – the relationship to a student. Teachers' socio-emotional development is always in the context of the teacher–student relationship, students' learning and the teaching environment. The Five Awarenesses of Teaching **(Rodriguez et al., 2020, see Figure 1)** is a framework that helps to organize our understanding of teachers as learners. The framework can describe the nature and factors that contribute to teachers' socio-emotional competence and well-being, and ultimately their implementation of student SEL. The framework posits five teacher awarenesses (awareness of: self-as-teacher, teaching process, student, interaction and context). It asserts that the purposeful development of these cognitive skills enables teachers to intentionally and successfully
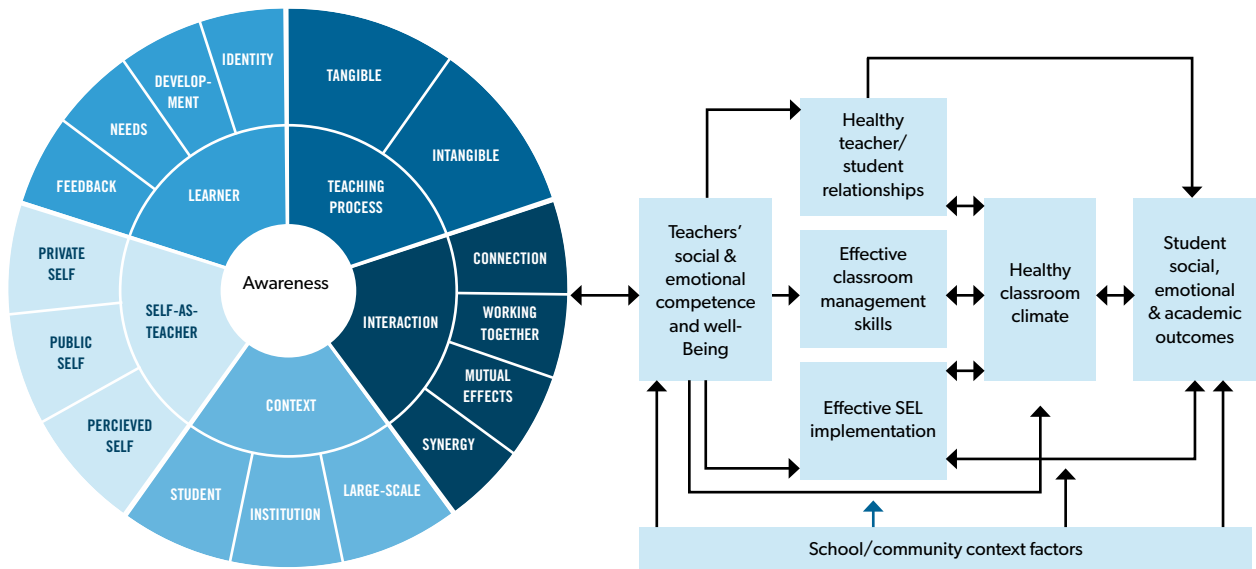
Figure 1 The Five Awarenesses of Teaching Framework. Source: Rodriguez et al. (2020)

develop and practise their socio-emotional skills. As a teacher's awarenesses grow (independently and in relation to each other) their SEL evolves accordingly. Teachers' awareness enables their ability to intentionally and successfully develop their socio-emotional skills and cognitive depth.

Why does teacher SEL matter for students' SEL? Among other things, the role of teachers is to support students' SEL. Teachers who have developed their teaching awareness recognize that their lens shapes how they view students and whether they believe students have achieved socio-emotional competence **(Rodriguez and**

> **The prevailing view of effectively practising SEL has been informed most heavily by a white-dominant culture that does not honour other cultural assets and funds of knowledge.**

Fitzpatrick, 2014). Like scientists, teachers form hypotheses about students based on observable data. Their perceptions of those observations are grounded in their personal lived experiences. When their hypotheses are correct, it can lead to high-quality teacher–student interactions and learning. However, when hypotheses are acted upon as if they are facts, it can lead to dangerous rigidity and bias in teacher practice (e.g. in the United States (USA), some people may rely on stereotypes about black boys having more challenging behaviours, girls being better at reading and writing, boys being better in maths and science, etc.) **(Delpit, 1988; Jacoby-Senghor, Sinclair and Shelton, 2016)**. Attempting to teach students SEL without developing teacher awareness does not set up teachers to handle cultural diversity and complexity appropriately or to be prepared to fully individuate their students.

SEL is deeply rooted in socio-cultural norms **(Madda, 2019; Simmons, 2019)**. The prevailing view of effectively practising SEL has

been informed most heavily by a white-dominant culture that does not honour other cultural assets and funds of knowledge **(Simmons, 2019b; Communities for Just Schools Fund, 2020)**. While this does not negate the value and importance of teaching student SEL, it does require teachers and leaders to intentionally (and in parallel) develop their socio-emotional skills to achieve personal socio-emotional competence. Such identity development allows teachers to focus and revise their hypotheses when they observe a student in need or a breakdown in the teacher–student interaction. Teaching practices are more likely to be successful when teachers can adjust their lens to understand their learners' SEL rather than teaching from an incorrect hypothesis **(Rodriguez and Mascio, 2018)**. Teachers foster the development of prosocial behaviours by modelling socio-emotional skills in their interactions with their students, their students' parents and other adults **(Jennings, Frank and Montgomery, 2020, in Chatterjee and Duraiappah, 2020)**. There is

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The COVID-19 pandemic offers a timely example of the intersecting roles of cultural, temporal and physical contexts affecting the development of SEL among youth.

a mounting call for deliberate practice **(Charness et al., 2005)** requiring teacher socio-emotional development through a racial equity lens that challenges deficit based models **(Aspen Institute, 2018; Love, 2019; Simmons, Brackett and Adler, 2018)**. This in-depth cognitive process directly contrasts teacher implementation of scripted interventions requiring directive behavioural techniques or student-centred best practices. The current landscape focuses heavily on developing student SEL via teacher implementation of programmes and practice. However, to support student socio-emotional skills, which are inherently grounded in socio-cultural norms, teacher SEL development towards achieving socio-emotional competence should be a prerequisite goal.

| **4.2** | **.2** | **.3** |

CURRENT CONTEXT AND LOOKING FORWARD

The COVID-19 pandemic offers a timely example of the intersecting roles of cultural, temporal and physical contexts affecting the development of SEL among youth. Firstly, the response to this virus is a potentially profound force shaping SEL for students in 2020 and beyond, one not faced by students in previous years. Although this pandemic affects people around the world, the response differs between nations, demographic groups and individuals **(McCoy et al., 2021)**. The effect of the pandemic on SEL may be more pronounced in communities that have been less able to control the spread and thus adolescents have been separated for longer periods from the social inputs that are valuable for their development. In turn, youths' peer relationships and peer group norms have influenced their likelihood of adhering to the various measures adopted to fight the pandemic **(Andrews, Foulkes and**

> One policy response to mitigate the impact of these intersecting tragedies on students has been mandating trauma informed teaching practices.

Blakemore, 2020). The recent global impact of the dual pandemics of COVID-19 and racial violence has highlighted the complex intersection between physical/mental health and structural racism. The current climate necessitates an advancement of our understanding of educators' experiences, especially those teaching children of colour in historically disinvested neighbourhoods.

Furthermore, COVID-19 has substantially altered educators' mental capacity and pedagogical practices, impacting their ability to establish healthy classroom climates and inhibiting their support of students' SEL. Mental health underpins teachers' ability to support these relationships and processes **(Hoglund, Klingle and Hosan, 2015; Greenberg, Brown and Abenavoli, 2016)**. One policy response to mitigate the impact of these intersecting tragedies on students has been mandating trauma-informed teaching practices **(NYC Division of Early Childhood Education, 2020)**. These student-centred practices are drawn from the discipline of social work **(Sanders, 2019)** and attempt to equip teachers with an understanding of approaches that can support students experiencing trauma. However, trauma-informed approaches often do not consider teachers' own experiences of trauma. COVID-19 has exposed teachers to unprecedented trauma and stress, having profound effects socially, emotionally and physiologically. These stressors, especially for teachers of colour, demand that teachers' SEL is supported as equally important and independent from student SEL **(Nagasawa and Tarrant, 2020)**. Efforts should be made to develop new culturally relevant tools for teachers to nurture their SEL in order to grow their ability to support students' SEL **(Sabic-El-Rayess, 2020)**. Directly attending to teacher SEL and identity development will better equip teachers to support their mental health and, in turn, better support students coping with trauma from a healing-centred perspective **(Ginwright, 2018)**.

Especially in these challenging

4

The assessment of SEL is pivotal in communicating SEL as a priority in education. In addition, SEL is contextually specific, and therefore assessment of socioemotional skills involves a broad range of interdisciplinary aspects.

times, nurturing educators' and students' flexibility, and minimizing the impact of negative socio-emotional experiences, is necessary for cultivating healthy young people. The education system is partly responsible for adolescents' socio-emotional development. Although more research is needed, a range of interventions (e.g. mindfulness and yoga, social and personal skills, family based) have been found to be successful in improving self-regulation in both children and adolescents, with improvement in academic, health and behavioural outcomes **(Pandey et al., 2018)**. As such, additional work needs to be done in incorporating more socio-emotional skill development into adolescent education and finding accessible ways to assess such skills in educational settings.

Studies confirm that intentional incorporation of SEL activities develops teachers' ability to find specific and measurable indicators of socio-emotional development of their students, thus allowing them to evaluate the implementation

of SEL process and to observe their own self-efficacy. Given that sometimes teachers perceive SEL as an additional workload, it is important to understand how to assess students' socio-emotional development and schools' socio-emotional climate.

4.2 .3

ASSESSMENT OF SOCIAL AND EMOTIONAL LEARNING

The assessment of SEL is pivotal in communicating SEL as a priority in education. In addition, SEL is contextually specific, and therefore assessment of socio-emotional skills involves a broad range of interdisciplinary aspects. Although it has been made clear earlier in this chapter that learning is inherently social and emotional, it is through the assessment of socio-emotional skills that we can see their impact on learning. Drawing on evidence from

across disciplines, this section provides a description of the skills, understandings and dispositions that can be assessed to measure SEL. In addition, it highlights principles that should be followed for socio-emotional skills to be assessed in educational settings.

FROM 'COMMON SENSE' TO QUALITY ASSESSMENT

As SEL is increasingly integrated in educational systems and curricula across the world, the need for quality assessment is ever more imperative. If schools are expected to teach SEL, the necessary tools for the assessment of such competences should also be available. Although skilled and experienced educators may have a keen sense of students' socio-emotional skills, dispositions and experience, our educational system cannot continue to rely exclusively on 'common sense' or 'hunches' in assessing whether students are learning or not **(Schonert-Reichl, 2020)**. Through a deeper

understanding of how socio-emotional competencies manifest in young people over time, and with the input of educators and youths **(RAND, 2018)**, we can develop an improved of SEL instructions and programmes **(see WG2-ch8** on curriculum and pedagogy for a critical take of SEL in curriculum and pedagogy).

Identifying and selecting a SEL framework for implementation in education is a critical first step, because a framework ideally lays out the theoretical context underpinning the suite of socio-emotional skills and dispositions that students need to be successful in school, life and work. A study conducted in 2017 identified many varied frameworks, including Positive Youth Development, Resilience, Character Education, School-Based Competency Development, Public Health, Mental Health and Mindfulness. One central finding that emerged was that '... different terms are used for competencies

As SEL is increasingly integrated in educational systems and curricula across the world, the need for quality assessment is ever more imperative.

that have similar definitions, and that the same terms are used for competencies that have different definitions' **(Berg et al., 2017, p. vii)**. Given this heterogeneity and inconsistencies in terminology, it is important to assess each framework on its own merits and outcomes, rather than on its theory or reputation alone.

| 4.2 | .3 | .2 |

KEY PRINCIPLES OF SEL ASSESSMENT

While the further development of SEL assessments is important in both education and policy contexts, we also acknowledge that socio-emotional skills and dispositions are interrelated. Many affect success in school and life beyond school, without initially being taught as such or even learned in the confines of a classroom **(Jones and Kahn, 2018)**. Crucially, the assessment of SEL needs to be underpinned by a number of key principles if it is to be meaningful, valid and useful. Firstly, it needs to be based on sound psychometric properties, making use of reliable and valid tools. Secondly, assessment needs to be culturally responsive, considering and addressing the social and cultural diversity of students. This helps to ensure transparency, fairness and equity and avoid the risks of stigmatization and reproduction of social inequalities **(Assessment Working Group, 2019)**. Thirdly, SEL assessment needs to be developmentally appropriate, reflecting the developmental changes taking place from early childhood to late adolescence with varying levels of difficulty and proficiency **(Denham, 2015)**. Fourth, SEL assessment needs to make use of strengths based tools that assess social and emotional strengths rather than social and emotional deficits **(Assessment Working Group, 2019)**. Fifth, rather than a single method or tool, multiple sources of assessment, such as teacher, self and peer assessment, and different assessment tools may need to be used depending on the task. Direct assessment is a very promising emerging tool in the assessment of SEL, but to

While the further development of SEL assessments is important in both education and policy contexts, we also acknowledge that socio-emotional skills and dispositions are interrelated.

…. there is increasing consensus suggesting an integrative assessment approach that makes use of different types of assessments that are both formative and summative.

date it is not yet practical to use for universal purposes **(Denham, 2015; McKown, 2015)**. Technology enhanced assessment of SEL is a burgeoning field, promising to make SEL assessment more feasible and accessible in teaching and learning. Sixth, self-assessment is another fundamental assessment principle particularly in SEL, encouraging a self-reflective and collaborative approach to learning, and enabling students to take more responsibility for their learning. Self and peer assessment are also more flexible in adapting to diverse learning needs and thus help to ensure equity in assessment **(Siarova, Sternadel and Mašidlauskaite, 2017)**. Finally, classroom practitioners need training and mentoring in developing, adapting and using SEL assessment tools, particularly formative ones, including guiding and supporting students in self and peer assessment **(Pepper, 2013)**. Each of these principles about high-quality, fair and informative SEL assessment aligns with principles of the ways in which we know socio-emotional skills develop and the way they are part

of the learning process.

Beyond assessing students' SEL, it is critical also to take a systems level view of SEL. Overall school climate should be assessed and inform school improvement efforts. This means considering the culture around care and relationships that is fostered by all school personnel from administrators to support staff. Assessment of governing bodies' support of policies that promote SEL, and relations to student well-being and performance, can also be helpful for informing and promoting SEL in a top-down way.

In conclusion, there is increasing consensus suggesting an integrative assessment approach that makes use of different types of assessments that are both formative and summative **(Denham, 2015)**. There is no magic bullet for assessing SEL, and the choice of method depends on the purpose of the assessment **(Frydenberg, Liang and Muller, 2017)**. Similarly, there is no single method suitable to assess all socio-emotional skills/dispositions: developing

4.3 Developing and implementing SEL in education

This section draws from the preceding sections to reflect on the directions that are being taken – and may be taken – in social and emotional foundations of learning. We want to consider hopeful possibilities, while acknowledging the speculative directions that may lead us to articulate even more impressive outcomes concerning the improvement of students' socio-emotional skills. This

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section discusses the implications of current research on SEL and well-being, followed by new perspectives based on indigenous, aboriginal and First Nations understanding of SEL. It then presents SEL programmes and SEL policies.

4.3 .1

SEL PRACTICES IN INDIGENOUS, ABORIGINAL AND FIRST NATIONS PERSPECTIVES

Indigenous cultures are continually fighting for the recognition of their identities, practices and traditions, including their right to retain their languages and resources and their ways of proposing educational practices. A consistent failure to understand an indigenous worldview has often been reflected in the absence of culturally appropriate forms of responsivity. Developing a

more complex understanding of knowledge, including acknowledging and accepting that multiple worldviews exist and are valid, is central to cultural competence and culturally responsive practices, even though it can be difficult to cultivate this more flexible epistemological stance. Enabling teachers to attend more specifically to the discernibly different aspects of indigenous knowledge systems supports not only their development of cognitive flexibility, but also that of their responsibilities to culturally responsive practice in their curricula. Appropriate SEL environments should involve this kind of culturally responsive pedagogy, and educators should be aware of the risk that Western style SEL practice could be incompatible with indigenous ways of knowing. In doing so, they are more likely to successfully support indigenous learners in using indigenous understandings of SEL to meet the educational aspirations and goals of their tribal communities, and the goals associated with Western educational attainment.

Understanding SEL through an aboriginal lens involves understanding the notion of belonging and its active influence in people's lives, where belonging is rooted in relationships with presences, places and people.

The examples presented here, drawn from various indigenous, aboriginal and First Nations contexts, present a limited selection aimed to explore similarities and differences identified in indigenous knowledge systems that seem most pertinent to education discussions today:

- a relational worldview in which connections and interrelations between living beings and the natural world are central to understanding the world and living in it;

- placing an emphasis on the big picture and its meaning, rather than the parts that make up the whole; a focus on acquiring knowledge through active engagement with, and direct experience of, the natural world;

- understanding 'competence' as the ability to actually put knowledge into practice in real world contexts;

- a more holistic view of human development, health and well-being; and

- transitioning these discernments to SEL approaches and applying them to education settings, such as those described in the next section. Geographic areas are considered in turn.

4.3 .1 .1

AUSTRALIA

Understanding SEL through an Aboriginal lens involves understanding the notion of belonging and its active influence in people's lives, where belonging is rooted in relationships with presences, places and people **(Rey, 2019a)**. Those relationships are underpinned by values and practices implanted through cultural Law/Lore, in particular respect for others and reciprocity. Law/Lore laid down before time, commonly called the Dreamtime, continues today as Dreaming **(Lee, 2013)**. Prior to 1788, with the invasion by the British, Dharug

clans cared for their Ngurrungras (clan areas within Ngurra), including their Presences. This involved caring for not only the physical Country, but also caring for Ancestors, through cultural practices that include transgenerational storying and what is called 'yarning,' largely defined as shared times/tellings **(Bawaka Country including Suchet-Pearson et al., 2017)**. Caring for Ngurra physically and spiritually involves collectives and coming together, whether for cool fire burning times, ceremonial times, celebratory times, or planting and harvesting the yams that were the staple dietary starch in local diets **(Pascoe, 2014)**. Caring for Ngurra thus meant social engagement and supporting communities. Strong communities are supported by strong families, and strong families raise strong individuals: strong in caring, connecting and belonging.

Young children raised with a strong sense of belonging, learn social and emotional well-being through their daily engagement with their families, their places of connection and their activities

(fishing with their mothers, collecting fruit and yam harvests, bringing healing and producing through plant knowledge, knowing the relationships across Ngurra between the arrival of certain animals, birds, fish, etc. with seasonal winds, rains and temperatures). When the children are older, the boys go with the men, their Elders and Uncles, to learn through initiation and other practices their roles as men, and the girls to learn 'women's business', with their Elders and Aunties.

Social, emotional, relational and well-being practices have been in place across Australia successfully for more than 65,000 years prior to 1788. However, Aboriginal social and emotional well-being has been decimated through colonization mentalities and actions that saw (and continue to see) restrictions on access to food supplies and the dispossession of Country; the denial of Aboriginal legitimacy in Aboriginals' own places; prohibitions on Aboriginal languages, ceremony and cultural practices; enacting

Young children raised with a strong sense of belonging, learn social and emotional well-being through their daily engagement with their families.

> SEL through communal collectives does not require a top-down imposed pedagogy.

and enforcing transgenerational incarceration experiences; and narratives that consolidate and compound dysfunctionality and disconnection, rather than respecting transgenerational storying of entwining, caring, cultural pride and belonging. Imposing, through mass education systems, 'his-storying', that not only embeds European and white colonialist power and privilege systemically, also silences and denies the Aboriginal presence from place (particularly in Sydney), as has occurred in Australia for more than 230 years. This is then reinforced by a patriarchal hegemony that divides and separates peoples into hierarchies of elitism through a knowledge system that privileges written codification over other forms of knowledge sharing **(Van Toorn, 2006)**. The proselytizing of Christian doctrines that have positioned global resources ('the Garden of Eden') as rightfully there for human consumption, without the respect or reciprocity required for caring and continuity, has undermined the strength and well-being of ecologies, human

and other-than-human **(Plumwood, 1993)**. Instead, human-centricity continues to divide and destroy the places of belonging, enacting mass extinctions on bio-diversities and in the process building globalizing industrial extinction complexes, which diminish and impoverish the waterways, the oceans and the sacred systems.

SEL through communal collectives does not require a top-down imposed pedagogy. Rather it requires recognition of the importance of the web of interrelatedness where human connecting, caring and belonging is grown through respect and reciprocity, walking with good spirit, within the weaving of presences, places and people, for the purpose of co-becoming and sharing times/tellings **(Rey, 2019a, 2019b)**.

| 4.3 | .1 | .2 |

CANADA

A cultural safety approach for indigenous students is increasingly

One of the avenues to be followed to enable social and cultural safety lies in the recognition of the traditional knowledge of indigenous women and the application of the holistic model of lifelong education of the First Nations.

implemented in Canadian post-secondary institutions, as a global social justice initiative to decolonize education **(Lévesque, 2017)**. The trauma of indigenous communities and the human rights abuses of former indigenous residential schools came into sharp focus in the summer of 2021 when hundreds of graves were found near Vancouver and Regina. In the province of Quebec, many issues related to intergenerational traumas and unfavourable living conditions still prevail today **(Joncas, 2018)**. In fact, in indigenous communities, socio-economic and socio-emotional precariousness often lead to forms of abuse with repercussions that mainly affect children and women **(Lévesque and Polèse, 2015)**. According to Colomb **(2012)**, indigenous adolescent girls are the most affected by chronic depression. In this regard, work on SEL could support their well-being and reveal its importance at the transitional stage that corresponds to college, where indigenous students, who seek to emancipate themselves from their condition, make their entry into civic life. The lifelong

learning holistic model of the First Nations **(CCL, 2009)** promotes the development of capable citizens to defend the cultural and linguistic interests of their nation, equipped to effect change at personal, community and national levels **(Dufour, 2016)**.

One of the avenues to be followed to enable social and cultural safety lies in the recognition of the traditional knowledge of indigenous women and the application of the holistic model of lifelong education of the First Nations **(CCL, 2009)**. The purposes of this model tend to seek a balance between the different dimensions of the person as necessary conditions for well-being: the body, the intellect, the emotional and the spiritual.

Artistic practice is at the heart of indigenous culture and, combined with other traditional skills, forms the breeding ground for identity **(Herring, 2011)**. From crafts to music, through storytelling and ceremonial dances, indigenous children are imbued from an early age with

Traditional Maori society valued high-level thinking and analytical skills, exemplified in their clear understandings of cosmology, geography, industry and learning.

the artistic culture of their family, their community, their nation. The United Nations Declaration on the Rights of Indigenous Peoples **(2007)** places art as a means of self- determination **(UN, 2018)**. The Canada Council for the Arts valuates indigenous art: '[We] will clear a path forward to self-determination and cultural sovereignty for Indigenous peoples without compromising our support for artistic and creative expression artistic expression' **(Canada Council for the Arts, n.d., p. 2)**. Creativity is an essential and inalienable aspect of indigenous culture, as artistic practice is entangled in traditional and contemporary spiritual values **(Herring, 2011)**. Indigenous well-being assessment tools such as the 'Native Wellness Assessment™' **(Thunderbird Partnership Foundation, 2022, p.1)** reveal that the connection to culture is an important factor of well-being **(Fiedeldey-Van Dijk et al., 2017)**. The creative arts, including theatre, are anchored in the traditional customs of the First Peoples **(Côté, 2017)**.

4.3 **.1** **.3**

AOTEAROA NEW ZEALAND

Traditional Māori society valued high-level thinking and analytical skills, exemplified in their clear understandings of cosmology, geography, industry and learning. Such skills, exemplified in various ways, were underpinned by SEL. For example, Māori practices of producing resources made from flax required a precise, socialized knowledge of the physical properties of raw materials, their source, the details regarding tikanga (customary practices) surrounding collection and processing, sustainability and so on. A second example shows that, as a result of successive generations of purposeful voyaging across the oceans, an intensive knowledge in this area was carefully acquired. Scientific endeavours were recorded and transmitted through socio-emotional approaches such as song, symbol, story, dance and everyday practices. These scientific endeavours and knowledge of Māori and other indigenous people, as well as their ways of transmitting this knowledge, are

seldom recognized as ways of knowing, and ways of teaching and learning.

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PACIFIC ISLANDS

Generally, learning in the Pacific is communal, and children's physical, social and spiritual environment is their classroom **(Lagi and Armstrong, 2017)**. Children's interaction with their elders or most knowledgeable adults and the environment contributes to the development of their SEL knowledge, skills and or intelligence **(Lagi and Armstrong, 2017)**. Pacific children learn through practice, modelling,

In an indigenous school environment, working on building a positive and caring classroom climate may be a lever for students' well-being and academic success.

observation, imitation and orally. Learning through practice, where an adult or most knowledgeable person scaffolds the child is the most effective way of learning **(Nabobo-Baba, 2006; Nabobo-Baba et al., 2012)**. Moreover, learning through practice promotes cooperative learning that encourages the development of SEL **(Lagi and Armstrong, 2017)**. For instance, when teaching a child to weave or cut toddy, the most knowledgeable adult will interact with the child through speaking and modelling how to weave or cut toddy. In the process of talking and teaching, the child learns to listen and be attentive, to respect, negotiate and cooperate with the adult **(Lagi and Armstrong, 2017)**. Furthermore, the child develops their language and thinking skills. The indigenous people of the Pacific's pedagogies are aligned to Bronfenbrenner's ecological theory, Vygotsky's socio-cultural theory, Gardner's multiple intelligence theory, Thorndike's social intelligence theory and Goleman's emotional intelligence theory **(Lagi and Armstrong, 2017)**. In the Pacific, teachers have

tried to use the same traditional pedagogies in schools. However, there are issues that prevent the effective use of these approaches.

4.3 **.1** **.5**

SEL PROGRAMMES IN INDIGENOUS CONTEXTS

In indigenous school environments, working on building a positive and caring classroom climate may be a lever for students' well-being and academic success. Indigenous children often grow up in conditions of emotional precariousness, which requires a particular sensitivity and sustained attention from teachers **(Maheux et al., 2020)**. School perseverance implies establishing a safe learning environment for children. Working on SEL contributes to creating these conditions conducive to learning and global well-being, which are at the heart of indigenous ways of learning. Integrating SEL into the daily classroom routine has an impact on the overall development of

Indigenous children often grow up in conditions of emotional precariousness, which requires a particular sensitivity and sustained attention from teachers.

the child, supporting a holistic approach to education **(Blanchet, 2019)**. The values of empathy and respect promoted by SEL also correspond to the precepts of peace education rooted in the intangible cultural heritage of First Peoples **(UNESCO, 2014)**.

Given the traumas generated by colonization, the cultural and human genocide suffered by indigenous peoples, and the still precarious living conditions they experience **(Maheux et al., 2020)**, it is important to focus on developing programmes that sustain well-being for new generations. For example, since the contribution of SEL had been little explored in the context of indigenous education, a Literacy of Emotions and Needs Educational Tool Program was developed in indigenous schools for the 11th First Nations of Quebec, Canada project **(Blanchet, 2019)**. This project pursued the objective of aligning research advances in SEL with indigenous school realities, in accordance with the holistic model of lifelong learning of the First Nations **(CCL, 2009)**. In an attempt to reach

the educational settings of the different learners' profiles in the various indigenous nations and to enhance their respective first languages, the emotion poster that forms part of the programme has been translated into the eleven indigenous languages spoken in the ancestral territory that represents Quebec. To this end, experts and elders members of various communities were consulted. After its launch at the Perseverance and Academic Achievement for First People Students Symposium in October 2017, various copies of the tool were delivered to the council of each nation in order for them to share it with their schools and raise awareness about the importance of making this learning a priority. It has also been made freely available on the internet and in workshops to enable communities to take ownership of the tool in their specific context.

By introducing a regular SEL-related educational practice in indigenous community schools, this tool might contribute to the development of an indigenous

> To fully grasp the essence of holistic learning, it is important to understand that indigenous peoples comprise hundreds of diverse communities, in terms of culture, language, governance and rights granted under treaties.

SEL pedagogy. Indeed, students evolving in a school environment that resembles them, that is sensitive to their needs, and where they can express themselves with confidence, will remain more persistent and have a better chance of success **(Shanker, 2014)**. While delivering literacy of emotions and needs, this educational tool is contributing to the well-being of more indigenous students.

To fully grasp the essence of holistic learning, it is important to understand that indigenous peoples comprise hundreds of diverse communities, in terms of culture, language, governance and rights granted under treaties **(CCL, 2009)**. The purpose of holistic learning tends to seek a balance between the different dimensions of the being, the body, the intellect, the emotional and the spiritual, as necessary conditions for wellness **(Colomb, 2012)**.

More generally, various publications reflect the potential of art education for the development of SEL among marginalized populations to promote the

democratization of knowledge, the recognition of diversity and the transmission of intangible cultural heritage. Beyond allowing the learner to create their own artistic language, it contributes to their emancipation, both emotionally and socially. Dupont's **(2015)** research highlights the impact of arts education practices on the overall training of the learner, perceived as a creator citizen. McManus and Jensen **(2020)** show that art education practice promotes the acquisition and retention of healthy socio-relational habits related to self-awareness and social awareness. Moore and Moore's **(2020)** explore the power of living art to develop self-awareness through the voice of values and worldview and to increase social awareness through the development of a sense of belonging. These authors maintain that an art based approach, where practice developing SEL promotes the recognition, validation and regulation of emotions, creates a safe space for participants to reveal their history, increase sense of justice, cultivate listening skills, affirm strengths and recognize

Anchored in work on emotion and relationship, social theatre practices have holistic potential in their adoption of a humanistic and global approach, with a view to transformation and emancipation both personal and social.

weaknesses. Similarly, Hatala and Bird-Naytohow **(2020)** explore the relationships between the performing arts, wellness and resilience of indigenous teenagers. Anchored in work on emotion and relationship, social theatre practices have holistic potential in their adoption of a humanistic and global approach, with a view to transformation and emancipation both personal and social **(Nascimento da Luz, 2016)**.

4.3 .2

PROGRAMMES

It is imperative to design interventions and intentionally foster school programmes that are grounded in the principles of SEL and can recognize and tackle inequities in education and society. Such principles promote the creation of safe, participative spaces in which power differentials can be challenged and replaced by an active co-construction of knowledge **(Sierra and Fallon, 2016)**. Interventions designed by both

researchers and educators have to take into account both the benefits and costs associated with working with what is, for most, a highly personal area of their existence (e.g. close human relationships). At the same time, the social, economic and cultural changes of today – from the COVID-19 pandemic to accelerated polarization within societies worldwide – make interventions that strengthen effective learning, social bonds, positive emotions and mental health an undeniable necessity on a global scale.

The focus of this section is to describe the programme benefits and costs of SEL interventions to individual learners, and their effectiveness in tackling inequalities in education, especially in light of emerging social, economic and cultural changes.

It is now well understood that universal SEL interventions from kindergarten to high school lead to improvements in students' socio-emotional skills, attitudes, behaviour and

> Many SEL interventions are grounded in research from developmental cognitive neuroscience that indicates that socio-emotional skills can be taught across a person's life span and are viewed as more malleable than IQ

academic performance **(Elias et al., 2003; Greenberg et al., 2003; Zins and Elias, 2007)**. Meta-analyses of SEL interventions from Pre-K **(Murano, Sawyer and Lipnevich, 2020)** through secondary school **(Taylor et al., 2017)** report significant positive outcomes of both universal **(Greenberg and Abenavoli, 2017)** and targeted interventions **(Murano et al., 2020)** in various forms, including whole-school approaches **(Hoffmann et al., 2020)** and for selective components of school experience **(Carroll et al., 2020)**. Such approaches to SEL take a staged or fabricated approach to SEL by creating learning situations that focus on SEL alone, when in fact all learning has social and emotional aspects. Many SEL interventions are grounded in research from developmental cognitive neuroscience **(e.g. Diamond, 2012)** that indicates that socio-emotional skills can be taught across a person's life span and are viewed as more malleable than IQ **(see section 4.2.1 on SEL development)**.

Previous evaluations emphasize several aspects of well-

implemented SEL programmes, such as fidelity, dosage, quality, responsiveness and adaptation **(Dane and Schneider, 1998; Durlak and DuPre, 2008; Feely et al., 2018)**. Fidelity or adherence corresponds to the extent to which an intervention is implemented as originally intended. It includes both content (what exactly has been done) and procedures (how the programme was implemented). In this aspect, it is crucial to provide teachers with specific training and external support to promote their understanding of SEL principles and increase their willingness to engage in maintaining the programme **(Martinsone and Vilcina, 2017a)**. The need to develop teachers' self-reflection and understanding of their own role in successful SEL is underlined by Martinsone and Damberga **(2017)**, who find that teachers reflect on their experience after the implementation of the SEL programme by focusing on their students' performance, rather than through addressing their personal socio-emotional skills and dispositions. Moreover, they identify a positive outcome in

terms of teachers' understanding of their roles when work during the implementation of SEL is monitored and regular support provided **(Martinsone, Ferreira and Talic, 2020)**.

Among the most effective approaches to SEL are whole-school programmes **(Greenberg et al., 2003; Baroody et al., 2014; Dusenbury et al., 2015)**, including not only direct teaching of socio-emotional skills in special lessons but also implementing SEL programmes outside of classrooms **(Oberle et al., 2016)** and fostering a relational school climate. The indirect SEL can be implemented through everyday teaching strategies and formative assessment **(Ferreira, Martinsone and Talic, 2020)**. One such programme was developed and tested in six countries in Europe **(learningtobe.net)**. In this particular approach, the standards of SEL and formative assessment strategies were integrated in one matrix, thus introducing teaching strategies specific to each aim of developing SES.

The promotion of a general understanding that SEL programmes are not only about students, but also invest in teachers' well-being, can contribute to effective SEL. Both direct and indirect SEL require teachers to serve as role models, sustain their own motivation to implement SEL programmes in all school settings, collaborate with colleagues and parents, and become involved in continuous education **(Jones and Bouffard, 2012)**. Such aspects as teacher's awareness of the importance of building relationships, school-wide support for positive behaviour and recognizing reflection as a part of learning are considered as key factors for successfully implementing SEL and creating a positive school climate **(e.g. Williford and Wolcott, 2015)**. Conversely, the implementation of SEL also encourages the development of teachers' own SES and improving their relationships with colleagues and students. Sometimes teachers perceive SEL as an additional workload; therefore, studies confirm that intentional incorporation of SEL activities

> The promotion of a general understanding that SEL programmes are not only about students, but also invest in teachers' well-being, can contribute to effective SEL.

SEL practices have been shown to help enhance self-regulation and awareness, as well as positive attitudes, and social orientations like empathy, foster cooperation, and reduce disruptive behaviours.

develops teachers' ability to find specific and measurable indicators of socio-emotional development of their students, thus allowing the teachers to evaluate the implementation of SEL process and to observe their own self-efficacy **(Martinsone and Vilcina, 2017b; Martinsone, Ferreira and Talic, 2020)**. Self-reflection could lead to a better understanding of teachers' role, namely that teachers are a part of SEL rather than external experts evaluating their students' performance **(as discussed above in section 4.2.2)**.

In more specialized contexts, such as designated school curriculum areas, SEL interventions have been successful at all educational levels in urban, suburban and rural schools **(Durlak et al., 2011)**, suggesting that many contexts would benefit from providing schools with such programmes **(Diekstra, 2008)**. SEL practices have been shown to help enhance self-regulation and awareness, as well

as positive attitudes, and social orientations like empathy, foster cooperation, and reduce disruptive behaviours **(Murano et al., 2020; Burnard et al., 2020)**. Focusing on the conditions conducive to well-being, several studies have led to the development of programmes to prevent problematic behaviours **(Greenberg et al., 2017; Taylor et al., 2017)**. SEL is implicated in academic and professional success, meaningful relationships, and enhanced well-being up to eighteen years post-intervention **(Taylor et al., 2017)**. Several mental health-related school programmes have been implemented, namely, life skills, personal and social skills, socio-emotional skills, prevention and SEL programmes. These programmes are differentiated in name, goals, theoretical background and duration. Despite their differences, they produced impressive outcomes concerning the improvement of students' socio-emotional skills, as indicated by international organizations such as UNESCO and WHO.

4.3 .3

RETHINKING RESEARCH AS PRACTICE - TWO EXEMPLAR INTERVENTIONS FROM TAIWAN

This section offers two intervention cases from the Ministry of Education's Digital Learning Sprout Project in Taiwan. Examples of educational practices can contribute to the improvement of learners' high order thinking skills and lead to emerging social and cultural changes.

4.3 .3 .1

FIRST INTERVENTION, A PRIMARY SCHOOL: LIGHTING UP THE OLD TRAIN STATION (LUOTS)

The Lighting Up the Old Train

Station project emerged from the sad news that the Tainan City Government decided to build a new train station, and the old station that ran for more than seventy years would be abandoned. A local primary school launched a school based curriculum, enabling teachers and children to work together collaboratively to save the community's collective memory. The project aimed to empower the pupils, transforming their creativity by lighting up the abandoned train station and encouraging them to make creative use of the idle space. Project based learning (PBL) and design thinking (DT) approaches were utilized throughout the project. The project also meets one of the United Nations' Sustainable Development Goals (SDGs) – 'Affordable and Clean Energy'. After lengthy negotiation with the Cultural Affairs Bureau, the City Government agreed to let the students light up and decorate the old train station based on the students' creative LUOTS designs.

The pupils completed the LUOTS project through five steps of DT.

SEL is implicated in academic and professional success, meaningful relationships, and enhanced well-being up to eighteen years post-intervention.

Picture 1. One of the LUOTS models made by a group of fifth graders.

1. Empathy: pupils are guided to conduct a field study in the local community and explore residents' needs.

2. Define: pupils are encouraged to identify what problems need to be solved to transform the old idle station into a beautiful recreation centre.

3. Ideate: pupils are encouraged to develop creative ideas by using brainstorming, forced relationships and six hats.

4. Prototype: pupils are transformed into 'makers', using 3D printing and laser engraving techniques to build scale models of the station and use Micro:bit and Arduino development boards to design the lighting of the station and come up with innovative electricity-generation ideas from the perspective of using renewable energy and changing residents' behaviours **(Picture 3.1 is an example)**; students calculate how many led light bulbs can be electrified and

figure out how to decorate the station using a limited amount of light bulbs; they are asked to do space planning, such as making a gallery/library of old station memories, a café, a playground and a souvenir shop.

5. Test: pupils go into the community and introduce the LUOTS project by showcasing their models and letting residents evaluate the appropriateness of their creative design.

SECOND INTERVENTION, A SECONDARY SCHOOL: KEEP BACK STRAIGHT (KBS)

The Keep Back Straight (KBS) project emerged from an idea that all students need to learn at school for almost ten hours every day (generally from 7.30 to 17.00) and spend most of their time sitting inside the classroom. Meeting one of the SDGs – 'Good Health and Well-Being', the KBS guides students to maintain a healthy

lifestyle through exercise and adopting a correct sitting posture. Using ICT and new technologies to improve students' physical and mental health, the school has completed a series of learning modules in recent years, including how to maintain a healthy diet, using wearable devices to monitor sleep quality, and engaging students in the use of a self-developed electronic 3D skipping rope to fight obesity and improve health. Similar to the previous case, PBL and DT approaches have been utilized throughout the four-year project to develop ways of helping the students sit with the correct posture.

The PBL KBS project enables pupils to work in small groups, in which they go through five steps.

1. Empathy: pupils are guided to conduct a field study, scrutinizing their own, and fellow students' and family members' incorrect sitting postures and behaviours.

2. Define: students identify two problems, including the

Picture 2. Three eighth graders wear Micro:bit enhanced devices to monitor sitting postures.

development of wearable devices to monitor sitting postures and then help maintain correct sitting postures.

3. Ideate: pupils are encouraged to develop creative ideas by using brainstorming, forced relationships, six hats and WebQuest.

4. Prototype: the 'makers' work

in small groups, using Micro:bit and other technological devices, to develop wearable devices **(Picture 3.2 is an example)**. The students are asked to come up with creative ideas to monitor their sitting postures correctly. Students learn the essential knowledge and skills in information technology, including programming, coding and computational thinking skills; health and physical education,

> **Young people's well-being is crucial for success in school, given its link with motivation to achieve academically.**

including sport, exercise, and health; integrative activities, including sewing techniques and the making of wearable devices; science and technology, including data analysis techniques and fine-tuning the products; arts and humanities, including how to better the aesthetics and ergonomics of the devices; language arts course, including how to promote products by using Microsoft PowerPoint and verbal and non-verbal communication skills.

5. Test: let fellow students, teachers and family members evaluate the appropriateness of their creative wearable devices. Furthermore, the school collaborates with the village chief and residents to make a health campaign, which expands the positive impact of the students' designs/inventions on the community and society.

In dealing with the problems encountered in real-world scenarios, using PBL and technology through interdisciplinary learning has

been prioritized in the Taiwanese 'Digital Learning Sprout Project'. A quasi-experimental design and mixed methods research approach have been utilized to identify both cases and effectiveness. Profound quantitative and qualitative evidence reveals that both of the above cases have positively impacted students' intrinsic learning motivation and 'five-c' abilities, including creativity, critical thinking, communication, collaboration and complex problem-solving. Furthermore, while the primary school case has improved students' empathy, the secondary school case has significantly improved pupils' computational thinking.

| **4.3** | .3 | .3 |

SEL PROGRAMMES AND WELL-BEING

Young people's well-being is crucial for success in school, given its link with motivation to achieve academically **(Wormington and Linnenbrink-Garcia, 2017)**, behavioural engagement with

> **Although it is laudable that interest has focused on well-being, it is essential to review and take stock of where we are now to consider how best to move forward to realize the potential of SEL interventions to promote well-being.**

learning including aspects such as (lack of) truancy **(The Children's Society, 2018)** and academic achievement itself **(Gutman and Vorhaus, 2012)**. It is therefore not surprising that policy initiatives have been introduced to promote young people's well-being. England, for instance, introduced the Social and Emotional Aspects of Learning (SEAL) programme as long ago as 2005 **(DfES, 2005)**, as a result of the Green Paper *Every Child Matters* **(DfES, 2003)** on the premise that socio-emotional skills underpin effective learning, learning behaviours and, of particular interest here, well-being.

Although it is laudable that interest has focused on well-being, it is essential to review and take stock of where we are now to consider how best to move forward to realize the potential of SEL interventions to promote well-being. As SEAL was widely taken up by schools in England, with an estimated 90 per cent of primary schools and 70 per cent of secondary schools utilizing the programme before it was officially discontinued and the materials

reportedly still being widely used **(Humphrey, Lendrum and Wigelsworth, 2013)**, it is worth focusing specifically on this programme. It is instructive to ask whether SEAL has been successful in promoting young people's well-being. The answer is that, despite the programme's popularity, the evidence is far from compelling. A government-commissioned evaluation of SEAL in secondary schools revealed that it had failed to impact socio-emotional skills, general mental health difficulties, pro-social behaviour or behaviour problems **(Humphrey, Lendrum and Wigelsworth, 2010)**. Evaluation of SEAL in primary schools was more promising, with one study indicating that teachers believe the programme has had an impact despite mixed findings in relation to children's self-reported emotions, self-esteem, social skills, and attitudes towards school and academic work **(Hallam, 2009)**, and another demonstrating a significant but small impact of small group intervention work across a range of socio-emotional skills **(Humphrey et al., 2008)**. It seems that SEAL may not have

> There is consensus that subjective well-being is 'a broad category of phenomena that includes people's emotional responses, domain satisfactions and global judgments of life satisfaction'.

fully delivered on its promise to promote well-being. However, the extent of its impact requires further scrutiny.

Firstly, it is necessary to consider what is actually meant by well-being. The original SEAL documentation refers to emotional well-being without defining this clearly. Although a range of disciplines from economics to development studies have problematized well-being, arguably the greatest concentration of work has been within the realms of psychology and psychiatry, linking mental health and well-being through the WHO's long-standing definition of health as 'a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity' **(WHO, 1948, p.1)**. While referring to mental and social well-being, this in itself does not expand on well-being; psychologists have made the case that what is important is how individuals experience and perceive their well-being, that is, subjective well-being, rather than objective indicators such as material circumstances given

that the same circumstances are experienced, interpreted and acted upon differently by different people **(Seligman and Csikszentmihalyi, 2000)**. There is consensus that subjective well-being is 'a broad category of phenomena that includes people's emotional responses, domain satisfactions and global judgments of life satisfaction' **(Diener et al., 1999, p. 277)**. It would appear therefore that SEAL was premised on fostering subjective well-being. However, based on Ancient Greek philosophy, psychologists recognize that feeling well, or hedonic well-being encapsulated by subjective well-being, is only part of well-being; another important facet is functioning well or eudaimonic well-being **(Waterman, 1993)**. Although the notion of eudaimonic well-being has gained traction **(Deci and Ryan, 2008b)**, there is little consensus on how best to conceptualize this, with a number of theoretical approaches put forward, including Ryff's six-facet model of psychological well-being **(Ryff, 2014)** and the core three needs fulfilment model within the self-

There is growing evidence from comparative studies that well-being is not understood in the same way in different contexts, as measures do not demonstrate measurement invariance across contexts.

determination framework **(Deci and Ryan, 2008a)**. Thus, in order to evaluate whether SEAL has been successful in promoting well-being, it is important to evaluate the programme against a more comprehensive model of well-being than appears to have been the case in the evaluations noted earlier, including both hedonic and eudaimonic aspects. While there has been some consideration of impact on mental health difficulties and self-reported emotion, which is to be welcomed, evaluation thus far clearly does not encompass the complexity of well-being.

But even if a more complex model of well-being had been considered in SEAL evaluations, a further issue is how best to measure well-being. There is growing evidence from comparative studies that well-being is not understood in the same way in different contexts, as measures do not demonstrate measurement invariance across contexts (i.e. they are not measuring the same thing in the same way). Measures of subjective well-being, in particular life

satisfaction, are widely used, with the seven-item Student's Life Satisfaction Scale **(Huebner, 1991)** being most frequently cited for assessing young people's life satisfaction. Yet, a recent large-scale international well-being study of over 16,000 young people in eleven countries concluded that while there was configural invariance (basic structural equivalence) in how life satisfaction was perceived in nine of these countries based on five of the seven items, and notably the United Kingdom (UK) was one of the two countries to which this did not apply, there was still not metric or scalar invariance in how the scale was being interpreted, making it invalid to directly compare mean scores across countries **(Casas and Rees, 2015)**. Such large-scale studies have yet to include less well-established eudaimonic well-being measures but studies testing the structure of models developed typically in WEIRD (Western, educated, industrialized, rich and democratic) contexts **(Henrich, Heine and Norenzayan, 2010)** in non-WEIRD contexts are also

insightful as a poor model fit raises questions about the nature of well-being in the context in question, as was the case when Ryff's model of psychological well-being was tested in China **(Gao and McLellan, 2018)**. While this discussion has focused on international comparisons, similar issues arise when considering different groups of young people even within one national context. There has been, for instance, some consideration of measurement

Although a range of assessment tools are available, these too need problematization given the accumulating evidence that well-being is not understood in the same way in different contexts, not only in different international contexts but also by different groups in society.

equivalence across gender, with the large-scale international study referred to above revealing some inconsistencies in item performance between girls and boys in some cultural contexts **(Casas and Rees, 2015)**. No similar work has been conducted focusing on potentially disadvantaged groups, although a Chinese study examining measurement invariance of the Children's Hope Scale, which while different from well-being is conceptually related, across different socio-economic status groups revealed the construct was not viewed in the same way by all groups **(Lei et al., 2019)**. Thus, it is imperative to problematize the context when framing well-being **(La Placa, McNaught and Knight, 2013)** and avoid imposing a model and assessment that may not be appropriate.

So, what can we conclude about how programmes are inscribed in local-level politics and policy? At first sight the implementation of SEL programmes, like SEAL and SEL, seems a positive step in fostering well-being, given its evident importance. However, the evaluation of such programmes from a well-being perspective is problematic when well-being itself is such a complex and contested construct. Although a range of assessment tools is available, these too need problematization given the accumulating evidence that well-being is not understood in the same way in different contexts, not only in different international contexts but also by different groups in society. It is particularly important that marginalized group's experience and perceptions are not overlooked by the dominant well-being discourse. Although this section has focused on well-being measurement issues, it is equally the case that the programmes themselves should not marginalize groups with a hegemonic view of SEL. Increasingly, critics argue this too may be the case **(Wood, 2018)**. This is an important debate that needs to be continued if young people are to experience well-being and flourish.

> More broadly, there has been growing concern from policymakers and practitioners about children and young people's mental health and its impact on learning, acknowledging that well-being is fundamental to flourishing.

NATIONAL SEL POLICY: A FOCUS ON THE UK

Recently there has been a renewed political focus on why some children and young people do not reach the standards expected and the causes of that failure. Since the importance and positive outcomes of SEL have been recognized worldwide, it poses questions for decision-makers about which programmes or approaches to implement in their schools. Current research **(Feely et al., 2018)** suggests that adaptation of programmes should not be considered a failure to achieve fidelity. A culture-specific programme adaptation could lead to forming the best practices crucial for the sustainability of the programme both on a national and international level **(Forman et al., 2009)**. Furthermore, national SEL programmes should be updated because of the dynamic and changing environment. For

instance, the original Latvian SEL programme **(Martinsone, 2016)** has recently been updated and edited to support the implementation of the new competence-based national education curriculum.

More broadly, there has been growing concern from policy-makers and practitioners about children and young people's mental health and its impact on learning, acknowledging that well-being is fundamental to flourishing. Issues including social media, social and environmental issues such as climate and equality, nutrition, and parenting practices have been recognized as affecting mental health. There has been increasing concern about the impact of abuse and exploitation of children and young people leading to an increased emphasis on the importance of safeguarding and ensuring that the voice of children and young people informs policy and practice.

Lavis and Robson **(2015, p. 5)** suggest that in an average class of thirty fifteen year olds:

Teachers need to feel confident to support students facing these social and emotional pressures to enable them to engage with learning.

- 'three could have a mental health disorder;

- ten are likely to have witnessed their parents separate;

- one could have experienced the death of a parent;

- seven are likely to have been bullied;

- six may be self-harming'.

Inevitably, therefore, many of these young people have had multiple negative experiences. While individual factors may fall below the threshold for external support cumulatively, they can have a significant impact on relationships, behaviour and learning. Teachers need to feel confident to support students facing these social and emotional pressures to enable them to engage with learning. Between 2016 and 2018, UK suicide rates for ten- to nineteen-year-olds increased by almost 30 per cent, rising from 204 to 263 deaths (Samaritans,

2019). The ways in which these issues have emerged in policy are varied but the language used in Every Child Matters (DfES, 2003), Getting it Right For Every Child (Scottish Government, 2006) and No Child Left Behind (NCLB, 2001) recognizes that what matters for children to learn and succeed is not a product of cognition alone and that socio-emotional development and well-being are crucial.

The Every Child Matters policy in England was the Labour Government's response to several tragic child abuse deaths. It introduced five indicators including 'enjoying and achieving', established a commitment to education, health, care and other services working together for children, and encouraged a whole child approach. This policy commitment was sustained throughout the 2000s, leading to substantial changes in practice, including schools providing well-being support such as breakfast clubs and access to wider services. While the legislation remains in place, the 2010 election

of a coalition government removed the central support for implementation and many schools reduced or stopped some of their wider service provision and put a greater emphasis on behaviour and standards. However, the commitment to multi-agency working continues to be a central part of government policies supporting well-being and SEL and is reflected across government departments. In England, Wales and Scotland policy-makers introduced and funded Violence Reduction Units (VRUs) taking a public health approach to tackling violence, developing collaboration across government departments and across services, including schools, in local areas to address the underlying causes of violence and take a preventative and early intervention approach.

VRUs will bring together police, local government, health and education professionals, community leaders and other key partners to ensure a multi-agency response to the identification of local drivers of serious violence and agreement to take

necessary action to tackle these. This includes being responsible for driving local strategy and embedding cultural change alongside their commissioning role as a means to make the VRU sustainable. We recognise that greater law enforcement on its own will not reduce serious violence and that we must continue to focus on early intervention and prevention. The introduction of VRUs across England and Wales represents a substantial and exciting system change in the field of violence (Home Office, 2020).

In Scotland, the Getting it Right for Every Child policy places well-being at the core of the policy and, unlike the initiatives in some other countries, which have been modified or even replaced as governments change, has been a consistent and sustained policy focus for nearly twenty years. The opening statement in the leaflet 'Understanding well-being' **(2018)** sets out that commitment in terms of the way that support is provided and its intended impact. Well-being sits at the heart of the

That greater law enforcement on its own will not reduce serious violence is recognized, as is the need that we must continue to focus on early intervention and prevention.

Getting it Right for Every Child approach and reflects the need to tailor the support and help that children, young people and their parents are offered to support their well-being. A child or young person's well-being is influenced by everything around them and the different experiences and needs they have at different times in their lives **(Scottish Government, 2016)**.

A whole school commitment and ethos, rather than piecemeal approaches, are key to improving well-being and standards - which can also reduce exclusions, re-engage students who have experienced problems, build good relationships, and attract and retain staff.

The Scottish policy's emphasis on relationships embodies the social and emotional aspects of learning and the way teachers are focused on how to resolve problems. In England, an emphasis on behaviour and the adoption in some secondary schools of zero tolerance behaviour policies has led to exclusions as incidents mount up and the child is seen as the problem. English and Scottish numbers of exclusions are markedly different with Scotland excluding only a handful of children each year, whereas England excludes several thousand annually **(McCluskey et al., 2019)**.

The 2010s saw an increasing public and policy concern about children and young people's mental health as England continued to perform badly in international measures of happiness and well-being. The policy debate often became polarized with well-being placed as an alternative to attainment and the English Government continued its emphasis on standards through the annual publication of school performance data. However, across the UK

policy-makers identified the importance of adopting a whole school approach to mental health and well-being. In 2014 **(updated in 2018)**, the Department for Education (DfE) published guidance on *Mental Health and Behaviour in Schools*, promoting a whole school culture fostering positive mental health and concluding that, in order to help their pupils succeed, schools have a role to play in supporting resilience and mental health **(DfE, 2018)**.

A whole school commitment and ethos, rather than piecemeal approaches, are key to improving well-being and standards – which can also reduce exclusions, re-engage students who have experienced problems, build good relationships, and attract and retain staff **(Gutman and Vorhaus, 2012; Brooks, 2014)**. Guided by the social and affective sciences, a series of policy commitments on mental health led in 2017 to a joint Green Paper from the Departments of Health and Education setting out a systematic, long-term approach

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Despite many schools relying on online learning provisions, governments were insistent on a return to face-to-face learning.

to mental health in schools and a review commissioned by the DfE of current practice, which was published the following year **(Brown, 2018)**.

Alongside well-being, policy-makers and practitioners have explored the development of resilience and character as a means of improving outcomes **(NatCen, 2017)**. In 2019, Ofsted revised its inspection framework to reduce the focus on data and introduce a 'personal development' judgement of how schools develop learners' character, resilience and values and what advice and support they offer learners to help them succeed in life **(Ofsted, 2019)**.

In 2020 governments internationally were keen to ensure that children and young people returned to education following extended school closures due to COVID-19. Despite many schools relying on online learning provisions, governments were insistent on a return to face-to-face learning. While economic reasons will have been important, there is, perhaps

unacknowledged, an awareness of the social and emotional basis of learning through interaction between pupils and with teachers and other adults. Fundamental to a successful return is the well-being of all children and young people. The Excluded Lives research project **(Daniels et al., 2020)** at Oxford University identified various scenarios experienced by children and young people that could impact on their re-engagement with school and were likely to increase the risk of them being excluded formally, informally or through self-exclusion. They proposed that to address these risks policy-makers needed an upstream approach with a nuanced understanding of vulnerability being about context and not just individuals, that recognized and promoted well-being as fundamental for all children and young people's learning, and identified and addressed policy contradictions and inconsistencies.

Practitioners expressed interest in developing their understanding and use of SEL as an integral

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part of teaching across the curriculum. In England and Wales, government departments and mental health organizations led by MindEd produced a set of resources ('Well-being for Education Return') that embraced social and emotional aspects of learning as children return to school, addressing the well-being of children, young people and teaching staff **(MindEd, 2020)**.

The policy debate often becomes polarized, with well-being placed as an alternative to attainment. However, we suggest that policy-makers need to address well-being and attainment as mutually supportive. They need to support whole school and multi-agency engagement using early intervention and prevention strategies and establishing policies and practices that are evidence based and sustained over extended periods to allow effective embedding, evaluation and evolution of practice. With the world potentially now facing a prolonged pandemic and its after-effects, well-being and the social and emotional aspects of learning

are more crucial than ever if our children and young people are to thrive and learn.

By adopting an interdisciplinary and interdepartmental approach, drawing on evidence from education, health and social care, including disciplines such as psychology and neuroscience, policy-makers can understand and address the social and emotional aspects of learning, and balance them with the cognitive and intellectual. Here we have focused on policies mainly in England and Scotland that sought to address the social and emotional needs of students and the nature of learning. Other policies exist and should be cultivated in other countries throughout the world. At the most basic level, a healthy SEL school climate and socio-emotional development requires young people to feel safe in school. Cohen and Espelage **(2020)** offer an insightful window into practices to promote school safety through bullying reduction and violence prevention in many different countries.

4.3 .5

IMPLICATIONS OF HUMAN SOCIAL, EMOTIONAL, AND COGNITIVE DEVELOPMENT FOR SEL POLICY: THE CASE OF ADOLESCENTS AND THE JUSTICE SYSTEM

As adolescents transition into adulthood, they encounter an increasing number of opportunities to make independent decisions. While scientific research suggests that adolescents are sometimes capable of making adult-like decisions, they also are more likely to make risky and impulsive choices compared to children or adults **(Icenogle et al., 2019)**. Although risk-taking is a feature of healthy development and can be prosocial (e.g. making friends, auditioning for a play)

As adolescents transition into adulthood, they encounter an increasing number of opportunities to make independent decisions.

(Duell and Steinberg, 2018), risky choices can also lead to dangerous outcomes (e.g. substance abuse, car accidents) **(Kann et al., 2018)**. Adolescents' risky behaviour therefore poses two important questions for societies: should adolescents be treated differently from adults when they break the law, given that risk-taking is part of normal development? Conversely, at what ages can adolescents be expected to make adult-like choices in different situations? Research on neural and psychological development can help answer these questions and drive evidence based policy-making about adolescence. A scientifically informed approach can allow societies to respond to, and reduce, adolescents' dangerous risk-taking, while also allowing adolescents the freedom to make decisions when developmentally appropriate **(Cohen et al., 2015)**.

Two research findings from developmental science are particularly relevant to policy: (1) social and emotional context is critical in understanding adolescent decision-making; and

> **A second key finding from developmental science is that adolescents are more sensitive to their experiences, making them more likely to change, for better or worse, compared to adults.**

(2) adolescent brain changes make them more sensitive to their experiences. Adolescents tend to take risks in affectively 'hot' or arousing contexts, like with friends or in highly emotional situations **(Steinberg, Icenogle and Shulman, 2018)**. In contrast, adolescents typically make decisions similar to adults in affectively 'cool' situations, removed from social and emotional contexts **(Steinberg, Icenogle and Shulman, 2018)**. This difference in adolescents' decision-making in different situations has been linked to differences in brain development across neural systems. Neural systems and psychological processes required for decision-making in cool contexts, where there is ample information and time for decision-making, operate at adult levels by around age 16 **(Luna et al., 2015; Icenogle et al., 2019; Steinberg and Icenogle 2019)**. However, systems necessary for making decisions in hot contexts involving social and emotional situations continue to change into the mid-twenties **(Casey et al., 2019; Andrews, Foulkes and Blakemore, 2020)**. In these affectively hot situations, adolescents' risk-taking

has been linked to heightened reward-system neural activity **(Chein et al., 2011; Smith et al., 2014, 2018)** and decreased self-control **(Cohen et al., 2016a, 2016b)** compared to adults. A second key finding from developmental science is that adolescents are more sensitive to their experiences, making them more likely to change, for better or worse, compared to adults **(Galván, 2014)**. This idea is linked to the finding that adolescence is a period of relatively increased neural change, or brain 'plasticity' (as dicsussed above) **(Spear, 2013; Fuhrmann, Knoll and Blakemore, 2015)**. Collectively, developmental research points to decision-making vulnerabilities in affectively hot, but not cool, contexts, and suggests that adolescents' brains are more amenable to change.

Scientific findings about adolescent brain and behaviour can inform legal policy-making **(Steinberg and Scott, 2003)**. Notably, these findings were summarized in amicus briefs from the American Psychological Association, and subsequently cited in several US Supreme Court decisions

(the highest judiciary court in the USA) that protect youth from harsh sentencing **(Steinberg, 2013)**. The Court argued that even for the most heinous crimes, the death penalty and life without parole constitute cruel and unusual punishment for adolescent offenders, because adolescents' risk-taking reflects normal development **(Cohen and Casey, 2014)**. Importantly, they also argued that adolescents' neural plasticity may make them more amenable to rehabilitation compared to adults, and that lifelong punitive measures are inappropriate for people who have a greater capacity to change **(Galván, 2014)**. The personal life narratives from youth who have been involved in the justice system reflect this reality **(Senghor, 2016)**.

These arguments are also relevant to less extreme cases of criminal behaviour, particularly when crimes are committed in hot contexts, like when friends are present (e.g. speeding while friends are in the car **(Bonnie and Scott, 2013)**. The idea that adolescents, compared to adults,

should be considered less culpable for criminal behaviour, and that they are more impacted by both good and bad experiences, also raises the question of what sort of repercussions are appropriate for adolescents **(Steinberg and Scott, 2003; Galván, 2014)**. Adolescents, and even young adults into their twenties, may be best served by a rehabilitative approach **(Casey et al., 2017)**. In line with this notion, recent research suggests that justice-involved adolescents with harsher treatment are more likely to reoffend, compared to those with lighter sentences focused on rehabilitation **(Beardslee et al., 2019)**. Thus, consideration of the context of adolescents' risk-taking and weighing potential increased capacity for change in adolescents can help societies address adolescent criminal behaviour in a developmentally appropriate manner.

Developmental science findings can also be helpful in devising policies or programmes that prevent dangerous risk-taking. Adolescent risk-taking may be attenuated by limiting

Developmental science findings can also be helpful in devising policies or programmes that prevent dangerous risk-taking.

> **Outside of social and emotional contexts, in affectively cool situations, developmental science suggests adolescents as young as sixteen are able to make adult-like decisions.**

opportunities to take risks in social or emotional situations. Graduated driving laws limiting the number of passengers allowed in a car with a teenage driver have proven effective in reducing fatal traffic accidents **(Chen, Baker and Li, 2006; Williams, 2007)**. Mentoring programmes, in and beyond developmental science, have also shown promise in preventing negative outcomes in at-risk youth **(Raposa et al., 2019; Burnard et al., 2022)**.

Outside of social and emotional contexts, in affectively cool situations, developmental science suggests adolescents as young as sixteen are able to make adult-like decisions. Such contexts provide ideal avenues for adolescents to make independent decisions and actively participate in society. Adolescents are able to make some independent medical decisions beginning at age sixteen **(Steinberg et al., 2009)**. Some developmental scientists have advocated for allowing adolescents to provide informed consent or vote by age sixteen **(Steinberg and Icenogle, 2019)**. Allowing adolescents to vote may

also increase the likelihood of their later civic engagement **(Hart and Atkins, 2011; Torney-Purta and Amadeo, 2011; Ruck et al., 2016)**.

In sum, ideas from scientific research can be applied broadly to create effective, just policies and practices. Such a scientifically informed approach protects adolescents when their risky behaviours result from normal development, and simultaneously allows adolescents the opportunity to participate in society to promote their independence.

4.4 Conclusion

Moving forward, SEL practices and policies should be responsive to context and culture, be informed by neurobiological development, and take educator's socio-emotional capacities into account. Research from diverse disciplines and geographies has converged to show that for young people to thrive in their schools, homes, communities and eventually the workforce, their socio-emotional development needs to be supported in each of those contexts. Unfortunately, youth often fail to receive this support. Healthy socio-emotional development, which progresses in a dynamic, non-linear, individually variable fashion across the life span, can be supported by strong interpersonal relationships with diverse others, opportunities for play and authentic engagement in meaningful cultural practices, and feelings of safety, belonging and autonomy. Given this focus on SEL in school aged people, we describe two developmental periods of especially significant socio-emotional growth and review programmes, interventions, assessment practices and policies geared towards promoting SEL in an equitable manner for all youth. In particular, we argue that future SEL school practices and government policies for students, teachers and all involved in the eco-system supporting youth development should be responsive to nested contexts and cultures and be informed by neurobiological and psychosocial development.

4.5

Key messages and recommendations

KEY MESSAGES: IMPLICATIONS FOR EDUCATION POLICY AND PRACTICE

- Learning is inherently social, emotional, relational and affective and both negative and positive emotions play a role in learning processes.

- Social, cultural, temporal and physical contexts, as well as aspects of identity, affect the experience of SEL.

- SEL is non-linear, dynamic,

Research from diverse disciplines and geographies has converged to show that for young people to thrive in their schools, homes, communities and eventually the workforce, their socio-emotional development needs to be supported in each of those contexts.

lifelong and shaped by contexts, relationships and neurobiological development. Although there are general trends in the developmental phase in which particular socio-emotional skills are refined, developmental patterns are not universal. Converging neurobiological and psychosocial evidence reveals early childhood and adolescence to be especially marked periods of development of socio-emotional skills.

- Play and creativity have an important role in supporting SEL from childhood to adulthood.

- Dedicated SEL interventions as part of formal education show significant results across all educational stages. Learners benefit from an individualized approach to supporting socio-emotional development and learning, but also from group/class-level interventions.

- Assessing students' capacities and proclivities for engaging socio-emotional skills is important

for helping them refine those skills and drawing educators' and policy-makers' attention to their development.

- In the Global North, indigenous perspectives on SEL are often quite different from psychological perspectives on the subject.

- Art is a significant mode of social and emotional education in many First Nations contexts in the Global North.

4.5 .2

KEY RECOMMENDATIONS: POLICY RECOMMENDATIONS, SUGGESTIONS FOR FUTURE RESEARCH

- Educators and students should be taught to recognize and support the development of SEL practices and reflect on their own socio-

Guided by indigenous perspectives and experiences, SEL practices can benefit from taking a more holistic approach, appreciating multiple possible worldviews and learning to teach in culturally responsive ways.

emotional skill development.

- SEL assessments should be inclusive whereby educators refrain from using goal structures exacerbating individual competition between students.

- Policy-makers are key players in addressing SEL change agendas as they work to make school and community policies more aligned with the science of socio-emotional development.

- High-quality SEL assessment should be psychometrically sound, culturally responsive, developmentally appropriate, multi-dimensional and responsive to students' assets.

- Dedicated SEL interventions should be implemented as part of formal education to support and facilitate students' SEL development, with different kinds of interventions (e.g. class-level, individualized) having different impacts.

- Adoption of interdisciplinary and joined up interdepartmental directives is essential.

- SEL practices that offer learners opportunities to contribute to the social world are central.

- SEL assessment should use integrative approaches and diverse tools by taking into account biological development and individual differences.

- Guided by indigenous perspectives and experiences, SEL practices can benefit from taking a more holistic approach, appreciating multiple possible worldviews and learning to teach in culturally responsive ways.

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CHAPTER

5

Foundations of academic knowledge

This chapter assesses the acquisition of academic knowledge and skills in domains including literacy, numeracy, sciences, arts and physical education. It examines how learning trajectories arise from complex interactions between individual brain development and sociocultural environments. Teaching literacy and numeracy to all students is a goal of most school systems. While there are some fundamental skills children should grasp to succeed in these domains, the best way to support each student's learning varies depending on their individual development, language, culture and prior knowledge. Here we explore considerations for instruction and assessment in different academic domains. To accommodate the flourishing of all children, flexibility must be built into education systems, which need to acknowledge the diverse ways in which children can progress through learning trajectories and demonstrate their knowledge.

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5.1

How do we understand the relationship between brain and cognitive development and the acquisition of academic knowledge and skills?

5.1 .1

HUMAN DEVELOPMENT AND LEARNING

It is increasingly being recognized that the course of child development varies across cultures and between individuals, and involves highly dynamic processes. Researchers understand development as a constant interplay between biological factors, such as genetics, and environmental factors, including socio-economic status (SES), leading to dynamic and idiosyncratic learning trajectories **(Elman, Bates and Johnson, 1996; Johnson, 2001; Karmiloff-Smith, 2009)**. The human brain continues to develop and change across the lifespan **(WG3-ch2)**, and education is associated with changes in cognition and brain function **(Brault Foisy et al., 2020)**. Early childhood is a sensitive period in development influenced by children's early experiences **(Shonkoff, 2010)**. Adolescence is also a sensitive period for development, underscoring the need to support students' developmental trajectories throughout the lifespan **(Fuhrmann, Knoll and Blakemore, 2015)**. Developmental journeys involve detours, regressions and complex interactions. Moreover, humans make sense and learn in ways that do not fit linear notions of hierarchical progression **(e.g. Fischer, 2008)**.

Therefore, we can think of education as offering environments that enable children to flourish, while recognizing that what it means to flourish depends on interactions among neurobiological, cognitive, socio-emotional, environmental and cultural influences, including communities' values and relations to place **(e.g. Hackett and Somerville, 2017)**. In an attempt to overcome binary thinking such as nature–nurture, intrinsic–extrinsic and internal–external, we have couched our chapter in terms of identifying intertwining factors that might pose risks to formal learning on the one hand and those that protect a child from

5.1 .2

KNOWLEDGE AND CURRICULUM

Debates about the content and purpose of school curricula abound; what and whose knowledge should be taught in schools is an ongoing debate.

adverse development on the other. Accordingly, the challenge faced in every country is to design educational systems that maximize flourishing for as many children as possible, with the recognition that no one educational system will be able to accommodate the flourishing of all children unless flexibility is built in and there is room for context-specific variations.

The curriculum is an organizing device that influences the way knowledge is framed and presented in the context of schools **(Bernstein, 2000) (WG2-ch8)**. for a more in-depth discusion. Debates about the content and purpose of school curricula abound; what and whose knowledge should be taught in schools is an ongoing

debate. Whether the curriculum should be organized as a collection of discrete subjects/disciplines or integrated areas as in child-centred approaches **(Bernstein, 2000)** and whether curriculum is a collection of disciplinary facts or a series of practices **(Hirst, 2010)** are issues of continuing debate. Critics of content-heavy, subject based curricula in various countries point to the way academic curricula disenfranchise minority groups who, it is argued, find it difficult to relate to decontextualized, abstract, disciplinary knowledge **(e.g. Zipin, 2009; Zipin, Fataar and Brennan, 2013)**. There is a long tradition of privileging academic formal knowledge considered important for schooling which often measures children's progress against 'a narrow subset of language skills' **(Hackett, MacLure and McMahon, 2020, p. 915)** that reflect the norms of the white middle classes of the Global North **(e.g. Viruru, 2001; Adair et al., 2017; Ahrenkiel and Holm, 2020)**. What counts as school knowledge is not universally recognized but is political **(Bernstein, 2020)**. Given

Debates about curricula raise issues about the role of children as active learners as well as power dynamics that infuse what counts as knowledge in societies and schools.

that disciplinary knowledge is generated by social and scientific groups, it follows that curricula can change and should be updated. However, change has been difficult to enact across schools systems **(see WG2-ch8)** for more on this debate. If curricular knowledge is contested then the prerequisite skills required to succeed in school have to be recognized as a subset of a much wider range of possible skills that children acquire as they grow up in different communities, societies and places. Debates about curricula raise issues about the role of children as active learners as well as power dynamics that infuse what counts as knowledge in societies and schools. What counts as academic success most often still involves formal knowledge aligned to Western Euro-centric epistemologies. It is our hope that 'what counts' as school knowledge will continue to be debated with the aim of building inclusive curricula that will enable all children to flourish. Throughout this chapter, we characterize learning in a way that we hope will acknowledge the diverse needs

of children across cultures. We have tried to accommodate the perspectives of multiple authors who were invited as experts.

We highlight the importance of recognizing that children's prior learning and experiences could interfere with or enhance formal school education. Children make sense through active participation in the practices of specific communities and the contexts in which they find themselves. A community's funds of knowledge **(Moll et al., 1992)** involve localized practices, rituals and 'ways of doing things around here' learned through participation **(Rogoff, 2014)**. For example, some children take part in social and economic activities such as street selling, shopping and storytelling that draw on community based forms of mathematics, literacy and thinking skills **(e.g. de Abreu, 1995)**. Such knowledge is situated and framed relationally with the contexts in which the skills take place. This involves context-dependent rather than abstract knowledge. For example, in her study of mathematics

Clashes between home and school ways of knowing can disadvantage children and young people if community funds of knowledge are not recognized or legitimized in school.

teaching in Brazil, de Abreu **(1995)** attempted to discover why some groups of children did far worse in mathematics in school than others. She found that the children who performed less satisfactorily helped their parents on sugar cane farms after school. Sugar cane farmers still use a mathematical counting system for estimating the perimeter of fields forged decades earlier by slaves. Farming mathematics uses estimates while school mathematics requires accuracy to two decimal places. de Abreu found that boys, especially, valued and used farming mathematics above school mathematics because they imagined themselves as future farmers. Moreover, teachers did not know about farming mathematics, which remained hidden due to its associations with slavery. When clashes exist between what schools expect and what is valued in other contexts, such as the home or community, considerable emotional labour, and cognitive and social identity work is required to manage these conflicts and this has consequences for academic success. Clashes

between home and school ways of knowing can disadvantage children and young people if community funds of knowledge are not recognized or legitimized in school. To become aware of the affects and traces of experience **(MacLure, 2016)** that make up funds of knowledge involves widening the purview of what is involved in learning. We need to recognize the extra-linguistic, affective, creative, embodied, condensed and situated ways of knowing such as farming mathematics in Brazil, that are often hidden in formal education settings. Making these visible requires scholars embedded in different cultural worlds to explicitly speak about alternative ways of knowing. This is an ongoing task, which has been given renewed urgency recently with calls to decolonize the curriculum.

Next we outline some prerequisite skills that provide children with a solid basis for flourishing in schools while recognizing that there are multiple skills that children acquire in non-school contexts that are typically

> Students who do not grasp basic numeracy and literacy skills in the early years tend to fall further behind their peers as they progress through school.

underplayed, invisible and discounted in schools **(Hackett, MacLure and McMahon, 2020)**

5.1 **.3**

PREREQUISITE SKILLS FOR EDUCATIONAL INCLUSION

While acknowledging differences between knowledge created in different ecologies of practice **(Stengers, 2010)**, such as communities and schools, this chapter aims to outline skills that enable children to learn in academic domains, including literacy, numeracy, science, physical education (PE) and the arts. In many domains, knowledge is cumulative. Students who do not grasp basic numeracy and literacy skills in the early years tend to fall further behind their peers as they progress through school **(e.g. Stanovich, 2009)**. Further, individual academic skills do not develop in isolation but interact with each other, and with domain-

general cognitive functions during development **(Peng and Kievit, 2020)**. Educational standards have often been criticized for setting age based targets that presume a fixed order of developmental phases for all children. This view does not fit with current knowledge of the dynamic and idiosyncratic nature of child development **(Elman, Bates and Johnson, 1996; Johnson, 2001; Karmiloff-Smith, 2009; Gorur, 2011)**. Thus, even if learning in different domains typically follows learning trajectories that schools endorse, individuals vary in how and when they acquire different kinds of knowledge.

Despite individual variability in learning trajectories, vocabulary and literacy skills are examples of prerequisite skills that are particularly important for acquiring new knowledge throughout school. As children become expert readers, they shift from learning to read to reading to learn **(Castles, Rastle and Nation, 2018)**. As will be discussed later in this chapter, learning literacy and numeracy requires learning culturally invented symbolic

systems **(Van Atteveldt and Ansari, 2014)**. The acquisition of these symbolic systems builds on the development of spoken language skills and quantity representations prior to and during early school years. Further, individual differences in foundational reading skills and print exposure predict changes in later reading comprehension **(van Bergen et al., 2018, 2020)**. Accordingly, one important future goal is to make high-quality early childhood education available for all children across socio-economic and cultural backgrounds **(Kagan, 2018)**. Pre-school education ideally includes embedded forms of learning, for example, learning through nature, play and participating in cultural activities which can be effective ways to get children acquainted with ideas that can bridge into formal learning **(Rogoff, 2014)**. The next section focuses on domain-specific cognitive prerequisite skills.

> Pre-school education ideally includes embedded forms of learning, which can be effective ways to get children acquainted with ideas that can bridge into formal learning.

5.1 .4

ASSESSMENT OF LEARNING

To enable children to flourish across academic domains, curricula and assessment methods ideally need to acknowledge the diverse ways in which children can progress through learning trajectories and demonstrate their knowledge. What is assessed in a school usually acts back on what is considered worthy to teach and how instruction is organized **(WG2-ch9)**. Any change to curricula and pedagogy usually involves paying attention to assessment. We ask, how can assessment methods be designed that align with recent insights from neuroscience which show a capacity for brain plasticity in all children, even if progression and trajectories differ **(Peters and Ansari, 2019)**? If it is accepted that assessment tasks already involve cultural, social and political choices about what knowledge is considered worthy, then it follows

> **... curricula and assessment methods ideally need to acknowledge the diverse ways in which children can progress through learning trajectories and demonstrate their knowledge.**

that there needs to be flexibility in what is assessed. In other words, inclusive assessment takes account of the cultural contexts in which children are growing up, with the aim of understanding a child's trajectory in terms of how academic skills are developing at the time of assessment, as well as their future learning potential **(Jeltova et al., 2007)**. One such

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BOX 1. DYNAMIC ASSESSMENT

approach involves dynamic assessment (DA) **(see Box 1)**. While assessment is discussed in more detail in **WG2-ch9**, here we emphasize that formative assessment is critical to support student learning.

DA has roots in Lev Vygotsky's (1930–1934/1978) work which was committed to capturing development in flow as concepts were developing rather than providing a static measure of assessment. DA points to future learning by referring to Vygotsky's zone of proximal development (ZPD). The ZDP indicates an area of sensitivity that measures what a child can do on their own and what they can do with assistance from more experienced others such as adults, some peers and, as we shall

discuss later, digital tools.

The main premise of DA involves, firstly, establishing the level of a student's performance by characterizing their current level of knowledge; secondly, following their progress as they acquire new knowledge; and thirdly, appraising their learning potential as new learning tasks are formulated **(Grigorenko and Sternberg, 1998)**. The classical DA process involves a highly deliberate sequence of assessment and teaching. Baseline assessment is followed by targeted teaching with corrective feedback and often multiple teaching-assessment components, culminating in a final assessment. The gain between the baseline and

It has been argued that Dynamic Assessment is better than static assessment tasks,it can predict educational trajectories and can support the design of useful interventions.

final levels of performance is conceptualized as a student's learning potential. So change is measured as the maximum level of performance. DA capitalizes on advances in psychometrics, specifically on adaptive testing. Adaptive testing permits the individualization and accurate calibration of a student's level of performance. It focuses on in vivo acquisition of knowledge, capturing ongoing learning and reassessing the student's ability to demonstrate the knowledge gained when they are exposed to a learning situation, in which the intent is to outdo their initial level of performance.

DA works well with digital technologies, for example, digital platforms for early reading acquisition, such as GraphoGame, because DA individualizes assessment tasks **(McTigue et al., 2020)** and uses ongoing real-time assessment. For example, while students acquire phoneme-grapheme representations, ongoing

appraisal determines what has been learned and what still needs to be learned. Modern DA are supported by complex measurement models permitting the direct estimation of learning potential, operationalized as the expected future score once the target concept or skill has fully developed **(McNeish, Dumas and Grimm, 2020)**. DA is highly usable in classrooms and other settings where digital platforms are available, and is also applicable for assessing the current and future performance of children with special needs, defined variously as their neurodevelopmental profile **(Naranjo and Robles-Bello, 2020)**, educational trajectories **(Cho et al., 2020)** or developmental circumstances **(Henderson, Restrepo and Aiken, 2018)**. Working with children with special needs or whose language is not that of the static assessments, DA can evaluate current educational skills and construct a child's

> ... current debates challenge Western epistemologies and raise questions of what counts as formal knowledge.

ZPD **(Zbainos and Tziona, 2019)**. It has been argued that DA is better than static assessment tasks **(Petersen et al., 2020)**, it can predict educational trajectories **(Petersen, Gragg and Spencer, 2018)** and can support the design of useful interventions **(Feuerstein et al., 2019)**.

5.1 .5

KEY QUESTIONS

Throughout this chapter we discuss and evaluate the state of research surrounding the prerequisite skills and concepts important for learning in the domains of numeracy, literacy, science, PE and the arts. We acknowledge that current debates challenge Western epistemologies and raise questions of what counts as formal knowledge. Below we draw from conceptual advances in the fields of early childhood studies, cognitive neuroscience, psychology and education

research. We have attempted to represent insights from diverse, and sometimes conflicting, viewpoints. The key questions addressed in this chapter are:

- what are the skills children need to learn to flourish in each academic domain?

- can assessment tools be aligned with evidence from cognitive and educational research to measure individual learning and development in each skill area?

- how can we design learning environments that help all children to flourish?

5.2 The interplay between cognitive skills and academic achievement

In many educational settings, attention focuses on individual educational outcomes, ensuring that children achieve the desired minimum skill level, or ideally flourish, for each outcome of interest. However, it is increasingly clear that 'no skill is an island' – rather, many socio-emotional and cognitive functions interact with one another and facilitate mutual growth which in turn relates to learning. Originally proposed as the theory of 'mutualism', this hypothesis posits that greater ability in one domain such as language, memory, arithmetic or reasoning, will support flourishing

Originally proposed as the theory of 'mutualism', this hypothesis posits that greater ability in one domain such as language, memory, arithmetic or reasoning, will support flourishing in other domains.

in other domains. A considerable body of work supports this hypothesis **(e.g. Kievit et al., 2017; Peng et al., 2019)**. A recent synthesis **(Peng and Kievit, 2020)** demonstrates interactions between tasks used to measure cognitive functions thought to be important for learning in multiple domains, such as working memory and academic performance.

Executive functions (EF) are a class of cognitive processes that are thought likely to facilitate academic performance. EF are a set of separable, but overlapping, skills that include response inhibition, interference control, working memory updating and set-shifting **(Friedman and Miyake, 2017; WG3-ch3)**. These are the functions required to focus and suitably allocate cognitive resources to the task at hand. Research finds that EF are correlated with school outcomes **(e.g. Bull, Phillips, and Conway, 2008; Cragg and Gilmore, 2014; Peng et al. 2018)**. Recent findings suggest that better executive functioning leads to more rapid, longitudinal academic skill growth. For

instance, Miller-Cotto and Byrnes **(2019)** find that better executive functioning drives more rapid improvement in reading and mathematics. Reciprocal developmental effects between EF and mathematical outcomes have been shown in several studies **(Fuhs et al., 2014; Schmitt et al., 2017; Wolf and McCoy, 2019)**. Beyond classic school settings, Prat et al. **(2020)** find that individuals with greater abstract working memory capacity show more rapid gains in computer coding skills in a high-intensity training setting. Similarly, Zhang and Joshi **(2020)** observe that better verbal working memory is associated with later reading ability. Brock, Kim and Grismer **(2018)** find mutualistic effects of EF, reading and mathematics. Notably, EF may not only drive the acquisition of academic skills, but these skills may also influence more rapid EF growth. In other words, in almost all the studies cited above, the effects are found to be reciprocal.

EF are malleable and improve over the course of development and formal education **(e.g. Bull**

... cognitive skills and academic outcomes have mutually beneficial, reciprocal effects, suggesting that even small differences and gains at early stages may lead to lifelong improvements in outcomes...

and Lee, 2014; Brod, Bunge and Shing, 2017). Spending time in school is associated with increases in EF skills (e.g., Brod, Bunge and Shing, 2017; Finch, 2019; Morrison et al., 2019), suggesting that the classroom is a great place to target EF. Despite the strong relationships observed between EF and academic skills, however, interventions targeting EF have had mixed success in generalizing improvements in academic outcomes (e.g. Diamond and Ling, 2019; Takacs and Kassai, 2019). For example, a meta-analysis finds no evidence that computerized EF training leads to better academic performance following training compared to control groups that were also treated with an intervention of some kind (Melby-Lervåg, Redick and Hulme, 2016). More evidence is needed to determine whether EF interventions can be effective in directly improving academic outcomes. Moreover, individual differences in children's EF are influenced by culture and SES (e.g. Howard et al., 2020; Ellefson et al., 2020; Xu et al., 2020). EF develop through social and cultural learning (Heyes, 2020)

and therefore must be assessed in the context of and considering children's prior knowledge, beliefs, values and goals (Doebel, 2020; Cybele Raver and Blair, 2020).

In summary, cognitive skills and academic outcomes have mutually beneficial, reciprocal effects, suggesting that even small differences and gains at early stages may lead to lifelong improvements in outcomes, illustrating the necessity of a detailed understanding of the developmental cascades between EF and academic outcomes. What has previously been imagined as discrete cognitive domains seems to be better explained by a more complex picture of mutual growth and reciprocity between them. Further research is needed to determine how EF develop in different cultural contexts, and how this influences relationships between EF and academic achievement. Bearing in mind that development is different according to academic domains even when cognitive functions are interrelated, the following sections discuss each academic domain in turn.

Further research is needed to determine how EF develop in different cultural contexts, and how this influences relationships between EF and academic achievement.

BOX 2: SKILLS FOR LONG-TERM RETENTION OF LEARNING: A TEACHER'S PERSPECTIVE

This section addresses the following question: How can we help children not only to learn, but retain information for years? A wealth of research suggests that strategies for successful learning involve three steps: encoding (initially learning something); storage (retaining something in mind over time); and retrieval (accessing information and bringing it to mind) **(Agarwal and Bain, 2019)**. However, when we look at classrooms, teaching often ends after the first two steps. Yet, research suggests that retrieval is paramount.

Students reap benefits from practising retrieval. It can bring about: increased learning and

Helping students learn with authentic tools and strategies protects against the pedagogies that emphasize assessment rather than the retention of knowledge.

retention of material; increased higher-order thinking; transfer of knowledge; and identification of knowledge gaps **(Roediger, Putnam and Smith, 2011)**. Research demonstrates that adding retrieval strategies to teaching increases exam performance **(Roediger et al., 2011)**. Strategies for retrieval practice are widely available. For example, low-stakes quizzing is a strategy frequently used to promote learning **(Pashler et al., 2007; e.g. retrieval practice.org)**.

Testing often occurs soon after a concept has been taught, and scores generally reflect learning. Yet, this learning is usually short-lived. Optimal retention of material occurs when there has been a delay after the original teaching **(Roediger and Karpicke, 2006)**. A key point is that material should be retrieved on at least two occasions, preferably separated by weeks. By employing intentional delay, retrieval is spaced.

Metacognition can be characterized as 'thinking about thinking'. Students often internalize failure because of poor test scores and this can be discouraging. Some eventually stop trying. Metacognition strategies can help students to discriminate what they know and what they do not know. This can help target their study and empower them to be accountable for their learning.

These strategies involve little or no cost and can be incorporated into various disciplines, curricula and teaching methods. These methods work for students of all levels. Helping stud ents learn with authentic tools and strategies protects against the pedagogies that emphasize assessment rather than the retention of knowledge. If we want students to retain knowledge, reach higher levels of critical thinking and transfer learning to new situations, one easy way forward is to incorporate retrieval tasks and metacognitive approaches into everyday classrooms practices.

5.3 Literacy Skills

Learning to read represents a major challenge in a child's development, and in our information society, reading fluency has become crucial for quality of life **(UNESCO, 2005)**. While many children achieve this skill successfully, children reach very different levels of reading fluency **(WG3-ch6)**. Worldwide, there are over 700 million adults who cannot read or write **(UNESCO, 2016)**. Further, a substantial group of adults, an estimated 15 per cent of the population on average, can be characterized as functionally illiterate, that is, having insufficient reading comprehension skills to navigate everyday life, despite having followed reading education during childhood **(OECD, 1997, 2013)**. Being unable to cope with society's literacy demands poses severe risks, such as adverse academic, economic and psychosocial consequences **(Undheim and Sund, 2008; Ibara and Ikiemi, 2021)**.

Literacy is a uniquely human form of social interaction. It refers to the human ability to read and

Literacy is a uniquely human form of social interaction. It refers to the human ability to read and write and enables individuals to communicate effectively and make sense of the world.

write and enables individuals to communicate effectively and make sense of the world. For millennia, humanity has used gestures, spoken language, images and movement to signal and share meanings. In today's world, literacy has come to be associated more closely with language. Extensive research in the fields of cognitive and developmental psychology has found that early language experience is fundamental to young children's speech and later literacy learning. Differences in the quantity and quality of parents' talk with infants has been associated with children's vocabulary learning and academic success **(e.g. Hart and Risley, 1995; Pan et al., 2005; Weisleder and Fernald, 2014)**, while differences in children's spoken word recognition and phonological discrimination can predict early vocabulary growth **(e.g. Tsao, Liu and Kuhl, 2004; Singh et al., 2012)**. It is important to note that children start formal literacy education at different ages worldwide and this contributes to variation in children's reading achievement **(Suggate, 2009)**.

5.3 .1

PREREQUISITE SKILLS FOR LITERACY

Fundamental to learning to read in a writing system such as English is the acquisition of the alphabetic principle **(Byrne, 1992)**. The alphabetic principle involves understanding that the visual symbols of the writing system represent sounds in spoken language. The prerequisite skills of phonemic awareness and letter knowledge are key precursors to this; children must be able to abstract the relevant phonemic units from the continuous stream of speech that they hear and identify the specific visual symbols of the writing system that correspond with each of those phonemes. Equipped with this foundational knowledge, children can begin to phonologically decode printed words for themselves, which allows them to generate the pronunciations of many printed words and,

> **The prerequisite skills of phonemic awareness and letter knowledge are key precursors ...**

through that, gain access to their meanings **(Share, 1995)**. An intimate and reciprocal association exists among children's letter knowledge, phonemic awareness and phonological decoding skill **(e.g. Hulme et al., 2012; Marinus and Castles, 2015)**.

As children progress in reading, their heavy reliance on phonological decoding gradually decreases **(Harm and Seidenberg, 2004; Zoccolotti et al., 2005)**. With increasing text exposure, they come to recognize more and more words rapidly and automatically, mapping their spellings directly onto meaning without recourse to decoding **(Castles and Nation, 2006; Nation and Castles, 2017)**. As they advance, children are also increasingly exposed to complex words of more than one morpheme, the minimum meaning-bearing unit in English. For example, 'farmer' consists of two morphemes {farm}+{-er}. Children's morphological awareness – their foundational ability to reflect on and manipulate the morphological structure of spoken words – has

been shown to be associated with later success in reading aloud and comprehension **(e.g. Carlisle, 2000; Deacon and Kirby, 2004)**. Thus, through building on solid foundational skills and with increased exposure to text, children move from 'learning to read' to 'reading to learn'.

5.3 .2

LITERACY DEVELOPMENT IN DIFFERENT WRITING SYSTEMS

Literacy development across scripts and languages shares similarities. For example, some basic graphemes, or symbols, must be memorized initially as the foundation for subsequent literacy. In many scripts, such symbols might be letters of the alphabet (as in German, Arabic or Greek) or letter-like representations such as abugida, as in Hindi. In others, they may be syllabic units that may or may not be comprised

of smaller units, for example, Chinese characters, Japanese Kanji and Korean Hangul. Regardless, all children learn a small subset of symbols and make use of this to read words. Sometimes, memorizing these basic symbols is aided through the use of songs such as the 'ABC song' in English or songs emphasizing vowels as in some countries in South America **(McBride, 2016a)**. Another universal is the pairing of symbols in print with phonological representations of these, that is, paired associate learning **(Hulme et al., 2007)**, for example, links between the letter gimel (g) which starts the word gamal (camel) in Hebrew.

One global concern in relation to literacy development is that over 50 per cent of the world's children learn to read in a language that is not their first language **(McBride, 2016a)**. This includes instances of diglossia, for example, the use of two variants of the same language within a community, as in formal versus colloquial Arabic, Swiss versus standard German, or African-American English **(Saiegh-Haddad, 2003; Saiegh-Haddad, Laks and McBride, forthcoming)**.

Some children are expected to learn to read in a completely different language from the one used in their family, for instance, when a colonial language is the medium of instruction but not of conversation. In many parts of India, the Philippines and much of Africa, textbooks may be in English but the family language is not **(e.g. Tupas and Lorente, 2014)**.

The opacity of orthographic systems impacts the time it takes to learn to read **(Seymour, Aro and Erskine, 2003)**. Language can differ in the transparency of the phonological system that the script represents. For example, transparent orthographies include Finnish and Italian while opaque orthographies include Danish and English. Scripts may also vary tremendously in the amount of visual complexity required to learn them **(Chang, Plaut and Perfetti, 2016)**. The 'inventory size' of symbols **(Nag, Caravolas and Snowling, 2011; Daniels and Share, 2018, p. 10)** varies to the extent that the time it takes to visually master a given script may vary by up to five years **(Chang, Plaut and Perfetti, 2016)**.

> One global concern in relation to literacy development is that over 50 per cent of the world's children learn to read in a language that is not their first language.

In relation to assessment, children's mastery of the key skills of phonemic awareness, letter knowledge and morphological awareness should be closely tracked at the initial stages.

Further, the semantic information conveyed by the script influences literacy learning. For example, most Chinese characters contain a semantic radical, a symbol that comprises part of the character representing meaning which is not pronounced within the character **(Shu and Anderson, 1997; Ho, Ng and Ng, 2003; McBride, 2016b)**. There is no clear analogy to this silent semantic representation in other scripts. In addition, in Chinese in particular, the one-to-one-to-one correspondence of syllables, morphemes and characters places the emphasis on the meaning conveyed by morphemes, for example, sun as in sunlight but not as in grandson. This and the high number of homophones (words that sound the same but have different spellings) and homographs (words that are spelled the same but have different meanings) in a script are particularly critical elements in early mastery of a language **(e.g. McBride-Chang et al., 2003; Ruan et al., 2018; Lin et al., 2019)**.

How children acquire literacy skills has clear implications for assessment and instruction **(e.g. Castles, Rastle and Nation, 2018; Seidenberg, Cooper Borkenhagen and Kearns, 2020)**. In relation to assessment, children's mastery of the key skills of phonemic awareness, letter knowledge and morphological awareness should be closely tracked at the initial stages. Emerging phonological decoding skills can be assessed with simple non-word reading tasks. As reading progresses, word reading efficiency and fluency can be assessed with timed word reading tasks. This can be complemented by dynamic methods to assess children's learning potential **(Jeltova et al., 2007)**. Systematic phonics programmes have been found to support early stages of learning in alphabetic languages/scripts **(e.g. Ehri et al., 2001; Torgerson, Brooks and Hall, 2006)**. Such programmes teach children grapheme–phoneme relationships in an explicit and sequenced way, providing them with the knowledge needed to independently decode as many words in the text as possible. Complementing phonics teaching with instructional methods aimed at building

children's oral vocabulary and background knowledge has been found to support reading comprehension **(Dickinson et al., 2010; Clarke et al., 2013)**, and can be especially relevant for optimal reading development in children across diverse socio-economic backgrounds **(Hart and Risley, 1995)**.

5.3 .3

A CROSS-CULTURAL AND CROSS-LINGUISTIC VIEW OF LANGUAGE DEVELOPMENT

There is an emerging consensus that strong early language skills provide a key foundation for later literacy and broader academic achievement **(Pace et al., 2019)**. Experiences such as high levels of back-and-forth conversation with adults **(Ramírez-Esparza, García-Sierra and Kuhl, 2014)** help children develop large vocabularies in toddlerhood **(Golinkoff et al., 2019)**.

As a result, two key markers for later literacy based on current evidence are conversational turns with adults and children's vocabularies.

However, current scientific evidence is based on studies in a narrow range of countries and does not represent global linguistic diversity. Over 90 per cent of psychological studies focus on children growing up in North America and Europe **(Nielsen et al., 2017)**, despite the fact that less than 15 per cent of the world's infants are born there **(Our world in data, 2020)**. Eighty-six percent of language acquisition studies focus on children learning Indo-European languages **(Slobin, 2014)**, only one of over 100 language families in the world **(Lewis, 2009)**. Moreover, given an Anglocentric bias, especially in reading research **(Share, 2008; McBride, Csumitta and Cantlon, 2021)** even Indo-European languages are not adequately represented.

As it turns out, it is difficult to measure proposed early markers across languages and populations.

... two key markers for later literacy based on current evidence are conversational turns with adults and children's vocabularies.

Recent initiatives – such as the Cross-Linguistic Lexical Tasks – to construct language tests for a large range of languages, including Indo-European languages, are moving towards more globally inclusive assessment and education.

Moreover, proposed markers may be culturally specific. To give an example of the measurement difficulties, it is hard to define what a 'word' is in certain languages, for example, when the word form varies depending on the sentence frame. It is extremely challenging to reliably measure a child's vocabulary in multilingual communities and those with considerable dialectal variation. Recent initiatives – such as the Cross-Linguistic Lexical Tasks **(https://multilada.pl/en/projects/clt/)** – to construct language tests for a large range of languages, including Indo-European languages, are moving towards more globally inclusive assessment and education. Anthropological studies suggest that frequent back-and-forth playful conversation between an infant and their mother is relatively rare and may be specific to onlya handful of communities **(Lancy, 2014)**.

Given these issues, it is crucial to develop our understanding of prerequisite skills for language and literacy beyond the typically studied populations. So far,

literacy research is dominated by populations in monolingual, urban, Western and Westernized places where literacy and formal education are prevalent. Such studies should not be generalized to the world's population. For example, a small-scale study finds that the amount of child-directed speech correlates positively with lexical development in an urban sample but does not correlate in a rural sample **(Vogt and Mastin, 2013)**. The underlying assumption is that parental stimulation improves language development. It is not clear why the pattern is different in rural communities, but one possible explanation is that young children in rural communities tend to interact more with their siblings than their parents as they age. Evidence on early language development across languages and cultures remains sparse, particularly in ways that connect with later literacy and academic skills, although see, for example, **Duranti, Ochs and Schieffelin (2011), Alcock and Alibhai (2013) and Stoll and Lieven (2014)**.

The challenge then is to develop metrics of early language acquisition that recognize linguistic and cultural differences and are good predictors of later language and literacy. One step in this direction is to adopt metrics based on, for example, everyday linguistic behaviour rather than decontextualized tests that are both difficult to standardize with respect to a norm group and open to cultural bias **(Styles, 2019)**. The second step involves widening the scope of the kinds of metrics adopted and considering the language-related skills that parents value and promote in diverse cultures **(Marfo et al., 2011; Harkness and Super, 2020)**. Thirdly, a battery of measurements representing a more holistic view of early language and communication skills could be used in longitudinal designs to assess their predictive value with respect to literacy and academic achievement. Ideally, all three steps should be undertaken in a coordinated fashion, with researchers across the world agreeing on data collection and analysis to improve comparability across sites. The recent rise in consortia among developmental scientists provides an optimistic setting for this **(Frank et al., 2017)**.

5.3 .4

SELECTED STRATEGIES FOR PROMOTING LITERACY DEVELOPMENT

Literacy is an essential skill that supports later academic achievement, expands individuals' access to information, and supports their ability to communicate with others **(Shanahan and Lonigan, 2010)**. These skills are particularly important for historically marginalized populations such as indigenous communities. Of the numerous strategies for supporting early literacy development, this section highlights two that are especially relevant for indigenous children: emphasis on concepts of print and teaching in mother tongue.

> The challenge then is to develop metrics of early language acquisition that recognize linguistic and cultural differences and are good predictors of later language and literacy.

> **... households that lack print, such as many poor, rural and remote communities, children have limited opportunities to build print concepts at home.**

5.3	**.4**	**.1**

CONCEPTS OF PRINT

Before children learn to decode letters and form words, they must pass through a 'pre-reading' phase of exposure to print **(Chall, 1983)**. Pre-reading may include adults reading to them or looking at books together. These activities expose children to text directionality, word spacing and book-handling skills, and the notion that print carries meaning, all of which are essential for understanding the purpose and logic of text **(Clay, 2017)**. In households that lack print, such as many poor, rural and remote communities, children have limited opportunities to build print concepts at home **(Rodriguez et al., 2009)**. Early education programmes for indigenous children can be developed to emphasize concepts of print before and alongside phonics instruction, in order to prepare children to learn to read.

5.3	**.4**	**.2**

MOTHER-TONGUE INSTRUCTION

Many sub-Saharan African countries use a former colonial language like English or French as the language of instruction. Raising awareness of the benefits of mother-tongue instruction is essential, as policy intervention in this domain might not lead to changes in practice unless teachers are informed about why home language as an early medium of instruction is important **(UNICEF, 2016)**. Because indigenous children rarely speak these languages at home, their experience is comparable to a child learning in a foreign language at school **(Magga et al., 2005)**. While all learners benefit from learning in a language they speak and understand, there are four key benefits to mother-tongue instruction for indigenous learners.

Firstly, instruction in one's mother tongue is the most efficient approach to teaching new content.

It allows learners to draw on their background knowledge and easily construct concepts for learning **(Benson, 2000; Collier and Thomas, 2004)**. Use of a language that is not familiar or understood drastically inhibits learning, as children are simultaneously learning a new language and attempting to learn content in that language **(Trudell and Piper, 2014)**.

Secondly, the structure of local languages is usually more conducive to efficient literacy learning **(Abadzi, 2013)**. Unlike English and French, most of the world's languages use transparent orthographies with consistent letter–sound correspondence. Evidence shows that children who have appropriate prerequisite skills can master the alphabetic principle and decode words independently in as little as 100 days, while the same milestone requires three years in English **(Abadzi, 2013)**. Metalinguistic knowledge and many prerequisite literacy skills acquired in mother tongue are transferable; learners who learn to read in mother tongue apply their skills to learn to read in second and third languages **(Cummins, 2009;**

Abadzi, 2013; Wawire and Kim, 2018).

Thirdly, use of local language enables participatory and non-rote learning. Learner-centred pedagogy is linguistically more demanding for teachers and learners **(Vavrus, Thomas and Bartlett, 2011)**. The quality of teacher–child and child–child dialogue is a key indicator of classroom environmental quality in the early years **(Justice et al., 2008)**. In many indigenous societies, children learn through keen observation and active participation, and these dynamics are important to replicate in the classroom **(Rogoff et al., 2003)**. Learners in a mother-tongue classroom can draw upon background knowledge and personal experiences, and express ideas using the full breadth of their vocabulary. This is particularly important for indigenous and marginalized children who have often faced generations of stigma as having inferior capacity as learners **(Young and Trudell, 2016)**.

Fourthly, mother-tongue instruction disrupts the replication of colonial hierarchies. Instruction

> …'multiliteracy' embraces the socially situated and multifaceted nature of literacy practices in diverse cultures and communities.

in colonial languages imposes mastery of that language as a condition to participation in formal education **(Johnson and Stewart, 2007; Trudell and Klaas, 2010)**. This effectively limits access to learning among children in certain ethnic and linguistic groups, replicating social and political inequality. Mother-tongue instruction elevates local languages to the same level of importance as former colonial languages **(McTurk et al., 2011)**. It is thus important for all children to see their language and culture reflected in school; mother-tongue instruction sends a message to children and caregivers that the school respects and welcomes their identity.

5.3 .5

MULTILITERACY AND MULTI-SENSORY APPROACHES

Many scholars have broadened conventional conceptualizations of literacy by turning to the concept of 'multiliteracy', which

embraces the socially situated and multifaceted nature of literacy practices in diverse cultures and communities **(e.g. New London Group, 1996; Lankshear and Knobel, 2006; Snaza, 2019; Pahl and Rowsell, 2020)**. The definition of multiliteracy used here refers to the constantly changing culturally available 'resources of representation' **(Kress et al., 2001, p. 6)**, including digital modalities such as the internet. 'Contemporary literacy or "multiliteracy" is now defined as reading, writing, creating, deconstructing, and understanding diverse texts from sources of print media and digital texts' **(Yelland et al., 2008, cited in Kirova et al., 2018, p. 245; Pahl and Rowsell, 2012)**. Multiliteracy recognizes the multiple forms of text found in everyday life (written, spoken, drawn, sung, audio-visual, printed, digital, etc.) and the diversity of media in which new kinds of text appear. For example, when reading on screen, users not only need to understand print, they also must navigate and read visual images, hypertext, graphic design, visual effects and audio elements **(Bearne, 2009; Flewitt, 2012; Erstad et al., 2020)**, as well as interactive

features and gesture- and speech-responsive interfaces **(Walsh and Simpson, 2014)**. Multiliteracy encompasses how texts are produced, interpreted and used for different reasons and in different places, and how different signs and symbols are used in diverse media in appropriate ways **(Cope and Kalantzis, 2000; Pahland Roswell, 2012)**. Multiliteracy is also closely linked to cultural diversity and tolerance, and is encouraged in promoting equality and understanding of the cultural contexts in which texts are produced and interpreted in creative and critically reflective ways. What are the implications of a multiliteracy perspective for young children's foundational literacy skills?

Whereas conventional approaches to literacy focus on the acquisition of clearly defined and autonomous skills, which are built up step-by-step, such as understanding how a letter represents a phoneme and knowing how to use this skill, a multiliteracy approach focuses more broadly on transversal competencies. Multiliteracy skills involve learning to think creatively and critically about

diverse approaches; producing and presenting texts in diverse media; choosing which signs, symbols and media to use; and how to engage an audience **(e.g. Godhe, 2019; Flewitt and Clark, 2020)**. Developing multiliteracy skills refers to having opportunities to practise interpreting and producing texts in a variety of ways as part of everyday life as children grow up in and adopt a culture and its practices, first as observers and then as confident participants in and influencers of that culture. It also involves participating in the activities of different communities.

Multiliteracy skills also relate to multisensory approaches to teaching and learning. These approaches refer to learning that involves more than one sense, where the senses are vision, hearing, touch, smell and taste. Movement is a multisensory behaviour yet it is often included in this list as well. While some learning approaches have focused on, for example, rote learning, research is pointing to the importance of hands-on, visual, auditory, and olfactory stimuli

Multiliteracy skills involve learning to think creatively and critically about diverse approaches ...

> **... there is a shift towards recognizing the importance of multiple senses for perception and learning.**

that are linked to the concepts and ideas to be taught. Neuroscientific evidence of multisensory processing and learning is relevant to education **(e.g. Matusz et al., 2019)**. This evidence has led to a shift from a hierarchical and modular view of the functional architecture of the brain, emphasizing uni-sensory perception, to a less hierarchical and distributed view, highlighting interactive multisensory functions **(Gobbelé et al., 2003; Pietrini et al., 2004)**. Further, there is a shift towards recognizing the importance of multiple senses for perception and learning **(Zangaladze et al., 1999; Murray et al., 2005; Pasqualotto, Dumitru and Myachykov, 2016)**.

As the sections above on multiliteracy and multisensory approaches suggest, research stresses the importance of considering language and literacy development from broad, socio-emotional and embodied perspectives. For example, Hackett and Somerville **(2017)** view young children's literacy practices as emerging from sound and movements that stretch

beyond individual human actions. They draw on interdisciplinary scholarship to argue that language involves more than words, syntax and meaning – and that literacy learning takes place at an ill-defined frontier between language and how language is experienced. Literacy learning accordingly is more than cognition and involves embodied knowing fostered through engagements with all kinds of matter including, for example, soil, buildings, sounds, landscapes and other non-human elements. They argue that the mobile, dynamic, relational and multisensory elements of learning involve something indefinable and irreducible to linguistic meaning. The term 'more-than-human' is used to acknowledge the role of all kinds of matter, including non-human matter such as objects, toys, tools, places and landscapes in learning. In sum, literacy learning can be fostered by supporting children's participation in dynamic, multisensory, collective events as well as by focusing on formal tasks that enable them to become acquainted with the systems of language.

5.4 Numeracy skills

Numeracy is an essential skill that supports academic development **(e.g. Duncan et al., 2007)**, yet many countries have low rates of numeracy. For example, one survey indicated that nearly half of working-age adults in the United Kingdom (UK) lack the

Mathematical systems vary across cultures and there are multiple routes to becoming mathematically literate.

mathematical knowledge that is expected of pupils in the early years of secondary school **(National Numeracy, 2019)**. Mathematical systems vary across cultures and there are multiple routes to becoming mathematically literate. There are large differences between countries as regards mathematics scores in international comparisons **(OECD, 2013; Mullis, Martin and Loveless, 2016)**. Countries value and approach mathematics teaching and learning in different ways **(Chiu and Klassen, 2010)**. Pacific Rim countries such as China, Japan and Singapore usually perform highest in international league tables. Cultural attitudes to mathematics are likely to be a significant influence: mathematics appears to be more highly valued in these countries **(Askew et al., 2010)**. Also, the amount of time devoted to arithmetic in school and in homework is likely to vary between different countries. Moreover, the amount and nature of initial training and continuous professional development available to mathematics teachers varies.

Lack of mathematical literacy has negative consequences both for individuals and for the economic and social welfare of the countries in which they live **(Parsons and Bynner, 2005; Gross, Hudson and Price, 2009; Rodgers et al., 2019)**. Mathematics is critical to participation in contemporary societies. For example, interpreting COVID-19 data and guidance requires knowledge of statistics and how to read graphs. Even so, school mathematics is a highly contested terrain **(Schoenfeld, 2004)**. Tensions around the very nature of mathematics revolve around issues such as abstract versus real-world, conceptual versus procedural, rational versus affective, and universal versus ethnomathematics. Ethnomathematics, introduced to the field by the Brazilian educator Ubiratan D'Ambrosio in 1977, studies the relationship between mathematics and culture **(Gutiérrez, 2017)**. It is discussed further in relation to mathematical pluralism in **section 5.4.4**. The next section reports the state of research relating to mathematics development and learning in terms of pre-requisite skills for access to formal, school mathematics,

Building upon children's earliest mathematical competencies are foundational competencies that form the basis of children's continued understanding and learning the 'big ideas' of mathematics – clusters of concepts and skills that are mathematically central and coherent, consistent with children's thinking, and generative of future learning.

rather than pluralistic, ethno- and everyday mathematics, which is discussed later.

5.4 .1

PREREQUISITE SKILLS FOR FORMAL NUMERACY

Mathematical knowledge begins in infancy and undergoes extensive development over the first five years of life. Infants can process a range of quantitative and geometric inputs **(Alcock et al., 2016; Lauer and Lourenco, 2016; Libertus, 2019)** and early number sense is correlated with later mathematical achievement, though underlying mechanisms are unclear **(Gilmore, 2015)**. For example, while early numerical knowledge includes many interrelated aspects, four skills are foundational to children's early development. The first is subitizing, the ability to quickly recognize or name the number of a group without counting. Subitizing begins early with children's sensitivity to number and appears to precede and support the development of counting, serving as the foundation for all number learning. The second is learning the ordered list of number words to ten and beyond, or verbal counting. The third is enumerating objects or saying number words in correspondence with objects. The fourth is cardinality or understanding that the last number word said when counting refers to how many items have been counted. These early prerequisite skills pave the way for children to move onto other relational (e.g. comparing numbers and patterns, structure and algebraic thinking) and operational (e.g. composing numbers, adding/subtracting, multiplying/dividing) number concepts. For example, pre-schoolers' understanding of the concept of cardinality, which is that the last number word used when counting indicates the total number of objects in a set, is an important prerequisite skill and is associated with later arithmetic ability when they enter

> ... the development of mathematical thinking is intertwined with the development of spatial thinking, which is the ability to reason about other dimensions of quantity, such as length, distance and size.

school **(Geary et al., 2018)**. Several studies have shown that young schoolchildren's ability to compare symbolic quantities (quantities represented by numerals and number words) is one of the strongest predictors of their future mathematical development **(Merkley and Ansari, 2016; Vanbinst et al., 2016)**.

Building upon children's earliest mathematical competencies are foundational competencies that form the basis of children's continued understanding and learning the 'big ideas' of mathematics – clusters of concepts and skills that are mathematically central and coherent, consistent with children's thinking, and generative of future learning **(Clements and Conference Working Group, 2004)**. These big ideas each include prerequisite skills and subsequent developmental progressions and can be organized around large conceptual domains including number, geometry and spatial thinking, and measurement.

The number domain includes

multiple big ideas, or topics: subitizing; counting; comparing numbers; composing numbers; adding/subtracting; multiplying/ dividing; fractions; and patterns, structure and algebraic thinking **(e.g. Clements and Sarama, 2021; Sarama and Clements, 2009)**. Although each topic includes prerequisite skills unique to its development in young children, it is also the case that the topics are interrelated and build upon one another, forming the foundation for later numeracy skills.

Moreover, the development of mathematical thinking is intertwined with the development of spatial thinking, which is the ability to reason about other dimensions of quantity, such as length, distance and size **(Newcombe, Levine and Mix, 2015; Hawes and Ansari, 2020)**. Mathematics is not just about numbers and arithmetic, but also involves geometry, measurement and proportional reasoning, which all require spatial thinking **(Newcombe, Levine and Mix, 2015)**. Geometry and spatial thinking can be broken down into multiple

Geometric measurement is an important real-world area of mathematics that can also help develop other areas of mathematics, including reasoning and logic.

big ideas: two-dimensional (2D) shapes, composing 2D shapes, three-dimensional (3D) shapes, composing 3D shapes, disembedding shapes, spatial visualization and imagery, and spatial orientation. Foundational to geometry learning is the understanding that shapes have different parts and properties that can be defined, as well as the understanding that shapes can be composed and decomposed **(National Research Council, 2009; Clements and Sarama, 2021)**. Spatial thinking, including spatial visualization and imagery and spatial orientation, are critical for (visual) subitizing, counting strategies, arithmetic, geometry, measurement, patterning, data presentation and other topics **(Sarama and Clements, 2009; Lauer and Lourenco, 2016; Clements and Sarama, 2021)**.

Geometric measurement is an important real-world area of mathematics that can also help develop other areas of mathematics, including reasoning and logic. By its very nature it connects the

two most critical domains of early mathematics – number and geometry. Included in this domain are length, area, volume, angle and turn measurement, as well as classification and data analysis. There are many foundational concepts to children's understanding of measurement, depending on what is being measured (e.g. geometric measurement of length, area, or volume). For length, for example, these include understanding of the attribute (e.g., length is one-dimensional), conservation (the length of an object does not change if the object is moved), transitivity (if A is longer than B and B is longer than C, then A is longer than C), equal partitioning (measuring length conceptually involves dividing the extent or object into equal-length intervals), iteration of a standard unit (measuring can be done by repeatedly covering an object with equal-size units), accumulation of distance (lengths can be added), and origin (on a ruler, there is a zero point) **(Clements and Sarama, 2021; Sarama and Clements, 2009)**.

> Parents' and teachers' attitudes towards mathematics can influence students' and children's mathematics achievement …

It is not only numerical and spatial abilities that contribute to mathematical development; more general abilities also play an important role, ranging from overall IQ to EF such as working memory and inhibition. Inhibition is the ability to suppress irrelevant and inappropriate responses and to ignore irrelevant information **(Gilmore et al., 2018)**. There are also relationships between mathematics, communication and language **(Morgan et al., 2014; Purpura and Reid, 2016; Sfard, 2015)**. Environment and education are also very important to mathematical development. Parents' and teachers' attitudes towards mathematics can influence students' and children's mathematics achievement **(Beilock and Maloney, 2015)**. Stereotypes about gender differences in mathematical abilities persist despite behavioural **(Bakker et al., 2018; Hutchison et al., 2019)** and neural **(Kersey, Csumitta and Cantlon, 2019)** evidence of gender equality in children's numerical abilities **(WG3-ch1)**.

5.4 .2

NUMERACY DEVELOPMENT IN DIFFERENT COUNTING SYSTEMS

Initially acquired as a meaningless string of words, the count sequence provides a foundation for the acquisition of counting, which is fundamental to numeracy development. In many languages, the first ten numbers (zero to nine) are distinct, primitive elements that can be combined with decade terms (e.g. ten, twenty) and multipliers (e.g. hundred, thousand, million) to form more complex numerals (e.g. twenty-nine, two hundred) **(see Hurford, 1987** for the syntactic rules that govern numeral combinations). Despite this, languages differ with respect to the transparency of the structure of numbers larger than ten. For example, in East Asian languages such as Korean and Chinese, and

These cross-cultural linguistic differences may impact children's basic numeracy skills. For example, Chinese-speaking children tend to count higher than children learning English as early as kindergarten.

also in modern Welsh, numbers larger than ten are constructed based on a transparent structure that reveals the base-10 system. For example, with regard to decade terms, twenty is 'two-ten' and thirty is 'three-ten'; and other numbers such as eleven and thirty-seven are represented as 'ten-one' and 'three-ten-seven' respectively **(Millerand Stigler, 1987; Dowker and Roberts, 2015)**. In contrast, in languages such as English or German, decade terms are less transparent (e.g. 20 is 'twenty'), and numbers between ten and twenty follow an irregular pattern (e.g. 'eleven', 'thirteen'). Further, in German or Dutch, the unit and decade terms are reversed (e.g. 37 is 'seven-and-thirty'), which obscures the relation between spoken and written numerals.

These cross-cultural linguistic differences may impact children's basic numeracy skills. For example, Chinese-speaking children tend to count higher than children learning English as early as kindergarten **(Miller and Stigler, 1987; Miller et al., 1995; Miller, Kelly and Zhou, 2005; Schneider et al.,**

Careful study designs that address additional environmental factors such as curricular differences, school environment and home numeracy practices in addition to linguistic factors are needed.

2020). This may be due to the fact that numbers in Chinese can be generated using combinations of words from one to ten and thus more clearly reflect the base-10 structure than English (e.g. 'two-ten-one'versus 'twenty-one' for the number 21). Cross-linguistic differences are also found in the reading and writing of Arabic digits **(Dowker, Bala and Lloyd, 2008; Zuber et al., 2009; Krinzinger et al., 2011; Xenidou-Dervou et al., 2015)**. Children learning languages such as German or Dutch are more likely to make inversion errors when asked to translate Arabic digits (e.g. writing 67 when hearing 'six-and-seventy' in German, equivalent to 'seventy-six' in English).

Effects of cross-cultural linguistic differences can also be seen in tasks that tap into more sophisticated numerical understanding, but these effects are more nuanced and are likely affected by factors other than the transparency of the count sequence. In some studies, Chinese-speaking children are shown to have better place-value understanding than English-speaking children, because they are more likely to represent double-digits such as 41 with blocks of tens and ones **(Miura, 1987; Miura et al., 1988)**. However, subsequent studies show that English-speaking children can also represent double digits in blocks of ten when they are provided with appropriate training and instructions **(Towse and Saxton, 1997; Saxton and Towse, 1998; Vasilyeva et al., 2014)**. Further, no cross-linguistic differences were found when children were asked to identify the decade and unit digit of a multi-digit number **(Krinzinger et al., 2011)**, suggesting that there might not be robust cross-cultural linguistic differences in children's place-value understanding. In other studies, cross-cultural linguistic differences were found in tasks that assessed children's ability to identify the successor of a given number, but only when the languages fell on different ends of the transparency continuum (e.g. English versus Hindi), and not when the language differences were relatively small (English versus Chinese) **(Schneider et al., 2020)**. Careful study

designs that address additional environmental factors such as curricular differences, school environment and home numeracy practices in addition to linguistic factors are needed.

5.4 .3

IMPLICATIONS FOR NUMERACY INSTRUCTION AND ASSESSMENT

Even the youngest children possess powerful beginnings of mathematical ideas, and they use and develop these ideas to make sense of their everyday activities. Throughout early childhood, young children's ideas can differ in significant ways from adults' interpretation. Educators can be encouraged to see things from their students' point of view and conjecture what the child might be able to learn or abstract from the experiences **(Sarama and Clements, 2009; Clements and Sarama, 2021).**

Despite their competencies, young children's ideas and their interpretations of situations are particularly different from those of adults, something early childhood teachers can be supported to recognize as they work to encourage children's early mathematical development. Therefore, teachers can be guided to interpret what the child is doing and thinking and attempt to see the situation from the child's point of view. Next we consider learning trajectories and how teachers can use them.

5.3 .4 .1

LEARNING TRAJECTORIES IN MATHEMATICS

Learning trajectories are descriptions of children's thinking as they learn to achieve specific goals in a mathematical domain, and a related, conjectured route through a set of instructional strategies and activities designed to move them through a developmental progression of levels of thinking **(Clements**

Learning trajectories include information on the foundational levels of understanding and skill for a particular topic.

> **Given a focus on reliability, summative assessment can have a distorting and narrowing effect on learning. This could be addressed by better aligning assessments with learning.**

and Sarama, 2004). Learning trajectories include information on the foundational levels of understanding and skill for a particular topic. They do not suggest a rigid view of development or teaching; rather, they support developmental approaches and formative assessment. Specific learning trajectories for early mathematics are available **(van den Heuvel-Panhuizen and Buys, 2005; Sarama and Clements, 2009; Blanton et al., 2015; Clements and Sarama, 2021; e.g. LearningTrajectories.org)**. Much is known about the stages children navigate as they learn to count **(Sarnecka, 2015)** but mapping later mathematical development is increasingly tricky **(Alcock et al., 2016)**.

There is substantial evidence on the value of feedback and formative assessment **(Black and Wiliam, 2012; Hodgen et al., 2018)**. Given a focus on reliability, summative assessment can have a distorting and narrowing effect on learning. This could be addressed by better aligning assessments with learning **(Nortvedt and Buchholtz, 2018)**.

INCLUSIVE MATHEMATICS EDUCATION AND MATHEMATICAL PLURALISM

Rather than privileging one perspective over another, embracing mathematical pluralism **(Hersh, 2017)** and ethnomathematics **(Gutiérrez, 2017)** can enable a more inclusive approach to mathematical literacy **(Solomon, Radovic and Black, 2016)**. This approach requires thinking beyond the dominant forms of school mathematics, which tends to privilege abstract, disembedded and disembodied aspects of mathematical systems. If adopted, mathematical pluralism can be empowering for children. Some argue that it leads to a more just mathematics **(Gutstein, 2006)**. Others draw attention to mathematics as a human

By accepting mathematical pluralism we can recognize that the affective, contextual and socio-political aspects of mathematics cannot be disentangled from the structural and cognitive aspects.

and more-than-human activity **(Thurston, 1994; de Freitas and Sinclair, 2020)**. Sinclair and de Freitas (2019) point to the role of the body and affect and implications for making mathematics accessible for all **(Abrahamson et al., 2019)**. With regard to primary school mathematics, Nunes, Bryant and Watson **(2009)** pay attention to the diverse ways in which children access key concepts and processes, including number, geometry, measurement, and multiplicative and proportional reasoning. They focus on children's use of diagrams, symbols and logic, modelling, problem-solving, and structuring activities such as equivalence and ordering. They pay attention to how children in diverse contexts create relationships between concepts and how they engender new concepts, so as to yield ever-expanding, inter-connected fields. This body of research underscores the efficacy of recognizing multiple representations **(Thurston, 1994; Nistal et al., 2009)** in mathematical literacies.

5.4 **.4** **.1**

DESIGNING INCLUSIVE LEARNING ENVIRONMENTS FOR MATHEMATICS LEARNING

By accepting mathematical pluralism we can recognize that the affective, contextual and socio-political aspects of mathematics cannot be disentangled from the structural and cognitive aspects **(Schoenfeld, 2016a)**. If we wish learners to have agency **(Schoenfeld, 2016b)**, have opportunities for playful inventive approaches **(Gutiérrez, 2017)** and engage in mathematical meaning-making **(Solomon, 2008)** we can support teachers to widen the purview of what has too often been a narrow approach to mathematics learning that emphasizes abstract, decontextualized and disembodied features. One way to facilitate this is by dialogic and collaborative learning **(Mercer and Sams, 2006; Boaler, 2008; Cobb, Zhao and Visnovska, 2008)**.

For example, mathematics can be taught with reference to imaginable contexts using learners' funds of knowledge and experience with a view to enhancing children's engagement, thereby creating more equitable education **(Gutstein, 2006; Civil, 2007; Nicol, 2018; van den Heuvel-Panhuizen, 2020)**. An emphasis on imaginative and real-world contexts is backed up by a growing field of research that recognizes the importance of multidisciplinary learning, in which mathematics is taught with science, technology, engineering and the arts, known as STEAM activities **(Quigley and Herro, 2016)**. There is also a growing trend in tinker spaces **(Wang et al., 2019)**, that is, spaces that enable children and adults to engage with the materiality of mathematics **(Nemirovsky et al., 2020)**. Despite evidence on the productive use of calculators **(Ruthven, 2009; Hodgen et al., 2018)**, the potential for digital technologies to transform learning **(Hoyles, 2018)** is only beginning to be developed. Recent developments in the field of Educational Technologies (EdTech) is testament to the potential of integrating technology into mathematics education **(Drijvers, 2018; Clark-Wilson, Robutti and Thomas, 2020).**

BOX 3: STEAM ACTIVITY EXAMPLE FOR MATHEMATICS LEARNING

Paper folding, or origami, is an accessible activity that challenges children's creativity and problem-solving **(e.g. Pope and Lam, 2011)**. The difficulty can be adjusted so that activities can be appropriate for learners of all ages. There are opportunities to apply mathematical concepts such as symmetry, mental imagery and spatial transformation. For sample activities, see https://nrich.maths.org/12235 and https://dreme.stanford.edu/news/math-paper-fold-some-math-your-day.

5.5 Cross-disciplinary academic domains

Literacy and numeracy provide prerequisite skills for learning and knowledge acquisition across academic domains and everyday life-tasks. There is, however, the need for a broader curriculum beyond literacy and numeracy in primary-level education. To flourish in society, students need access to a wide range of academic domains such as the arts, sciences and PE. Some research suggests that these domains are interrelated. For example, as noted above, STEAM education refers to the integration of science, technology, engineering, the arts and mathematics **(De la Garza**

> **... visual art is associated with visual-spatial thinking, suggesting that it overlaps with geometry and other mathematics and science skills.**

and Travis, 2018). Arts education seems to have a positive impact on creative thinking **(Winner et al., 2013)**, and visual art is associated with visual-spatial thinking, suggesting that it overlaps with geometry and other mathematics and science skills **(Goldsmith et al., 2016)**. A full review of each domain is beyond the scope of this chapter, but some important considerations are summarized in the following sections.

5.5 .1

SCIENCE EDUCATION AND CONCEPTUAL CHANGE

Science education contributes to children's critical thinking and conceptual reasoning skills within a broader societal context. Disciplinary knowledge in science and engineering can be described as practices and habits of mind that frame concepts. Core concepts include structure, function and scale **(NGSS Lead States,** 2013**)**. Critical shifts in how science education is conceptualized are necessary for developing a scientifically educated world population. These include (1) framing science in terms of conceptual change and a process of building towards more powerful explanations individually and societally and (2) driving towards deeper structural understanding of core principles including the complex forms of causal interaction and systems thinking that exist in science and beyond.

Research shows that scientific understanding is built by trading up for increasingly explanatory models **(e.g. di Sessa, 2016)**. This is true both at the societal and individual level. Our knowledge advances by discarding earlier explanations for increasingly informed ones. We have seen this historically as people came to understand Earth as a sphere and we have watched it more recently as scientists learn more and more about COVID-19 such that advice to the public has evolved alongside the science. Education must account for how

scientific knowledge advances by giving students the opportunity to revisit concepts at increasing levels of sophistication. Equally important is that learners are taught how the process of trading up for increasingly informed explanations in science works and to understand the role of evidence in developing and revising scientific explanations **(McNeill and Berland, 2017)** – lest they mistake the process of building knowledge that advances and increases in explanatory power for the belief that science is simply wrong much of the time.

> Current discourse in educational pedagogy encourages deeper learning mostly in the form of active processing, but with insufficient articulation of what characterizes the deepest forms of understanding.

Current discourse in educational pedagogy encourages deeper learning **(Martinez and McGrath, 2014)**, mostly in the form of active processing, but with insufficient articulation of what characterizes the deepest forms of understanding. Deeper, more expert understanding involves discerning the structural knowledge that frames concepts **(Grotzer, 2002)**. Expert knowledge typically includes: a reflective sense of how concepts are structured; embedded

assumptions; and epistemic origins of the information. This requires an understanding of the causal framing of concepts and being able to reason about complexity and systems dynamics **(Yoon, Goh and Park, 2018)**. These assumptions may differ between levels of explanation **(White, 1993)**. For instance, explanations of individual contributions towards climate change often focus on the additive aspects of specific actions while explanations at the societal level should draw upon distributed causal patterns that have potentially synergistic interactions leading to emergent outcomes that are not aligned with individual intent **(Grotzer, Solis and Derbiszewska, 2017)**. Deep understanding of science requires revealing these structural aspects, their potential to be transferable to new areas of knowledge, and the affordances and limits of the information. A focus on the processes and nature of science, such as conceptual change, and on structural knowledge, such as that of causal complexity, invites an understanding of the power and limits of science as a lens for

> **The urgency of climate change provides a focus to accelerate the translation of these existing pedagogical principles into educational praxis.**

knowing the world that interacts with public literacy and trust.

EDUCATION FOR SUSTAINABLE DEVELOPMENT

Here we focus on environmental education. There is now a long tradition of environmental education supported by numerous United Nations (UN) environment/education colloquiums (e.g. Belgrade, in 1976, Tbilisi in 1977, Brundtl and in 1987 and Rio in 1992). However, the journey has been long and complex **(Gough, 2014; Somerville, 2016)** with 'educations' taking a range of positions such as climate, peace, values, environmental sustainability and sustainable development, to name a few. **The Delors Report (International Commission on Education for the Twenty-first Century, 1996)** commissioned by UNESCO highlights four pillars of learning:

learning to know; learning to do; learning to be; and learning to live together, with the earlier **Faure Report (International Commission on the Development of Education, 1972)** advocating lifelong learning as central to quality education. Arjen Wals' **(2012) UN-DESD Report** identifies key pedagogical attributes for sustainability: learning-based change; integrative; problem-based; critical; creative and exploratory forms; visionary leadership; participation; social networking; and lifelong learning. Other UN reports have underlined the need for inclusion and diversity in education **(Tilbury and Mula, 2009; UNESCO, 2015)**.

Environmental education has been given renewed urgency with growing public awareness of the damaging effects of human activity on the planet **(see WG3-ch7** for a discussion on learning spaces). The urgency of climate change provides a focus to accelerate the translation of these existing pedagogical principles into educational praxis **(Somerville, 2017) (see WG1-ch4** on learning to live with nature).

Post-human and new material approaches to pedagogy advocate breaking down binaries such as subject and object, human and nature, and children and their everyday environments.

The term 'Anthropocene' refers to the period of time during which human activity started to influence planetary systems in highly detrimental ways **(Zalasiewicz et al., 2010)**. Awareness of human-induced climate change, for example, is accelerating the need for new pedagogies that recognize the ways in which humans are entangled with the planet **(Somerville, 2017)**. Post-human and new material approaches to pedagogy advocate breaking down binaries such as subject and object, human and nature, and children and their everyday environments **(Crinall and Somerville, 2019; Hackett, MacLure and McMahon, 2020)**. Considerable advances in early years pedagogy recognize how children are entangled with the world that has the potential to contribute to environmental education **(e.g. Somerville and Green, 2012; Somerville, 2014; Pacini-Ketchabaw and Taylor, 2015)**.

Some common threads are emerging as pedagogical principles for environmental education, such as the significance of place-based learning which relates to concepts such as

relocalization, reinhabitation and decolonization **(Greenwood, 2003; Somerville, 2010; Somerville et al., 2011; Greenwood and Smith 2014; Tuck and McKenzie, 2015)**. Post-human approaches are rethinking the human subject as part of Nature Culture **(Haraway, 2003; Dollin, 2020)**,which requires a child-centred, participative, inquiry based pedagogy **(Rautio, 2013; Rautio and Stenvall, 2019)**. Emphasis is also being given to recovering indigenous ways of knowing **(Pacini-Ketchabaw and Taylor, 2015; Karki et al., 2017; Smith, Tuck and Yang, 2019)**. Transdisciplinary thinking is drawing attention to ecological systems in terms of complex, relational, inter- and interdisciplinary knowledge **(Capra, 2015)**. The need for holistic literacies that involve head, hands and heart is also a feature of new work on environmental education **(Gandhi, 1937; Germein and Vaishnava, 2019)**. Intercultural pedagogies that celebrate cultural diversity while redressing inequalities are also required **(Tilbury and Mula, 2009; Solis and Callanan, 2016; Mukherjee, 2017)**.

> **... protective pedagogies interrupt the status quo of education, a status quo which, as climate activist and scholars argue, urgently needs disruption.**

Protective pedagogies reposition the human, emphasizing that humans are inextricably entangled with the planet. Some examples of such pedagogies are happening, for example: in an Australian preschool, where new literacies are emerging through play with mud **(Cole and Somerville, 2020)**; in a groundwater project in Rajasthan and Bangladesh, which has produced ecological and community insights using photovoice methods with children involved in local inquiry **(Chew et al., 2019)**; and in Scotland, where students walking traditional droving routes enacted an entangled interdisciplinary, intergenerational, interspecies and place-responsive approach interrupting conventional pedagogical frameworks **(Mannion, 2020)**. These protective pedagogies interrupt the status quo of education, a status quo which, as climate activists and scholars argue, urgently needs disruption **(Mannion, 2020)**.

5.5 .3

MUSIC EDUCATION

Music plays a unique role in the perceptual and cognitive development of listeners from around the world. Much like language, musical elements can be rearranged in an infinite number of ways to create songs that convey emotional meaning, transfer information within and across generations, and elicit cooperation **(Jackendoff, 2009)**. Two primary elements of music are pitch and rhythm. Pitch is the perception of how high or low a tone sounds, whereas rhythm is the pattern of time intervals between notes unfolding in time. Rhythm in music gives rise to the sensation of a beat, or the underlying pulse in music. Every known culture has music **(Brown, Merker and Wallin, 2000)** and requires the listener to develop knowledge of their culture's system for using pitch and rhythm to create and comprehend the meaning of their culture's music **(Hannon and**

Trainor, 2007). Prerequisite skills in music include the ability to learn musical pitch relationships and the rhythmic conventions of one's culture in order to participate in music-listening and music-making processes. Specific skills, such as the ability to perceive if two melodies are the same or different, to match pitch, or to clap your hands along with the beat of music are not trivial and take well into childhood to master **(Welch, 1994; Corrigal and Trainor, 2010; Nave-Blodgett, Hannon and Snyder, 2020).** Together, pitch and rhythm abilities provide the building blocks for other creative arts activities, such as dance, theatre, musicals, choir, band and orchestra.

Music's melodic and rhythmic structure helps listeners predict when and how the next note of a melody will arrive. Listeners' brain responses to rhythm have been shown to facilitate the processing of speech (i.e. better synchronization to speech rhythms) when it is sung compared to when it is spoken **(Vanden Bosch der Nederlanden,**

Joanisse and Grahn, 2020), suggesting that musical structure could aid language comprehension. As teachers have long known, music can be used as a tool for aiding comprehension in the classroom by setting words to songs. There is also evidence that music education is associated with phonological skills and reading achievement **(e.g. Zuk et al., 2013; Habib et al., 2016).** Using music outside arts classrooms is important for setting up an environment that is conducive for learning through the intrinsic enjoyment of music as well its structural features.

Engagement in music has been found to regulate emotions and promote social bonding from infancy to adolescence **(Savage et al., 2020)**. Children can be encouraged to develop perceptual abilities through exposure to many different genres of music around the world. Early musical skill assessment should not be overly concerned with children's accuracy in pitch, rhythm or movement reproductions to music, but also their level of engagement, cooperation and perception of

As teachers have long known, music can be used as a tool for aiding comprehension in the classroom by setting words to songs.

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emotion. To promote long-term engagement and benefits from arts education, as described in the literature above, children can be encouraged to find musical activities or other forms of artistic expression, including the visual arts and acting, that capitalize on their own interests and abilities.

5.5 **.4**

PHYSICAL EDUCATION

Decades of evidence show beneficial effects of physical activity on physical health and well-being **(Kannel and Sorlie, 1979; Penedo and Dahn, 2005; Warburton and Bredin, 2017)**. More recently, it has been found that PE has benefits for mental health **(Penedo and Dahn, 2005; Biddle et al., 2019)**. The benefits of PE for cognition **(Donnelly et al., 2016; Marques et al., 2016; Iri et al., 2017; Bidzan-Bluma and Lipowska, 2018)** in childhood have also been proven. Further, being physically active in early childhood tends to track into adolescence and adulthood **(Herman**

et al., 2009; Telama et al., 2014; Hayes et al., 2019)**. Therefore, promoting participation in physical activity during childhood is vital for the development of a physically active society.

Despite this, there are challenges in getting PE recognized and valued as a core subject in schools, and participation in PE remains low **(Martins et al., 2020)**. Potential barriers to the successful implementation of PE are: the low status of the subject; lack of teacher training and agency; and limited facilities and equipment in schools **(Martins et al., 2020)**. The mixed nature of the evidence for the relationship between physical activity and academic achievement may also contribute to these barriers. While the majority of evidence points toward a beneficial effect **(Lees and Hopkins, 2013; Marques et al., 2016)**, teachers often have to argue that time spent doing PE in school does not take away from academic achievement **(Donnelly et al., 2016)**. Some studies have demonstrated a negative effect of PE participation

on academic achievement **(Beltrán-Carrillo et al., 2012; Howard et al., 2016; Kerner, Haerens and Kirk, 2018; Packham and Street, 2019; Simonton and Garn, 2020)**. A randomized controlled trial of a vigorous physical activity intervention in schools did not find significant improvements in students' fitness, cognitive abilities or mental health, but the trial suffered from a high drop-out rate and low-implementation fidelity **(Wassenaar et al., 2021)**.

Risks of PE that need to be considered include the impact on children who are undernourished or food insecure and for whom participating in physical activity might take away from vital energy resources that are needed for academic learning **(Howard et al., 2016) (see WG3-ch2** for a discussion on nutrition and brain development). In these cases, high-intensity physical activity might need to be avoided and emphasis placed instead on the social, emotional and cognitive aspects of PE that relate to health education **(Howard et al., 2016)**. Further, poorly implemented PE

has the potential to negatively impact self-esteem and increase the incidence of bullying **(Kerner, Haerens and Kirk, 2018; Packham and Street, 2019; Simonton and Garn, 2020)**. Further, corporeal movement repertoires have gender significance that overlap with cultural mores of acceptable performances of masculinity and femininity **(Butler, 1993; Young, 2005)**. School and cultural expectations can lead to increased absenteeism, disciplinary issues, and even anxiety and depression in children, all of which can negatively impact academic achievement **(Packham and Street, 2019)**.

Certain characteristics of physical activity interventions and PE have been identified that can help to guide a PE curriculum **(Zach, Shoval and Lidor, 2017)**. Specifically, effective PE incorporates cognitive challenges, such as problem-solving, strategic thinking and learning new skills **(Diamond and Ling, 2016; Howard, Vella and Cliff, 2018; McNeill et al., 2019)**. It can focus on personal variables such as goal-setting, self-esteem-building and self-regulation **(Howard, Vella and**

... poorly implemented PE has the potential to negatively impact self-esteem and increase the incidence of bullying.

> **... participation in physical activity tends to decline as children enter adolescence, and this is particularly so for girls.**

Cliff, 2018; OECD, 2020). For younger children (e.g. in the foundation phase), play and exploration can underpin PE; however, as this is a critical time for the development of motor skills **(Lubans et al., 2010)**, the teaching and refinement of these skills can be emphasized. For older children and adolescents, focus can be placed on health education and student well-being. Research has shown that participation in physical activity tends to decline as children enter adolescence, and this is particularly so for girls **(Telama et al., 2005; Xu et al., 2020)**. This highlights the importance of PE curricula that help children find joy in movement from a young age and keep students active throughout their school career.

Schools have been recognized for the important role they play in the promotion of physical activity as they present the most cost-effective opportunity for intervention **(Lees and Hopkins, 2013; Marques et al., 2016; Messing et al., 2019)**. For some children, school may be the only opportunity they have to partake in good-quality, safe and meaningful PE **(Beni, Fletcher and Chróinín, 2017; Messing et al., 2019; Trigueros et al., 2019)**. Research to date has highlighted that PE should be inclusive, enjoyable and expose children to different ways to be active to ensure they have the tools needed to lead a healthy and physically active lifestyle. To understand how to expand participation in areas of PE requires sensitivity to diverse cultures embodied in community practices that invest corporeal repertoires – such as large and small movements, and strength and docility – with gender values as well as aiming to expand and challenge these.

5.6 Conclusion

This chapter has examined research on the acquisition of academic knowledge and skills in domains including literacy, numeracy, sciences, the arts and PE. The scholarly contributions in this chapter lead to important and multifaceted insights on prerequisites for academic knowledge that can be summarized in the following key findings and implications.

Research suggests that academic and cognitive skills gained in a variety of contexts have direct reciprocal interactions with each other and other domains during educational development, and these interactions facilitate mutual growth.

5.6 .1

KEY FINDINGS

- It is increasingly being recognized that the course of child development varies across cultures and between individuals, and incorporates highly dynamic processes that involve interactions among neurobiological, cognitive, socio-emotional and environmental, cultural influences, including communities' values and relations to place.

- Critiques of the dominance of Western Eurocentric accounts of child development are mounting, which in turn highlight political and power dynamics involved with what counts as curricular knowledge in which contexts. For example, most of the research has been conducted on children growing up in North America and Europe, but less than 15 per cent of the world's infants are born there.

- While what is meant by flourishing depends on transversal interactions among many elements (neurobiological, cognitive, socio-emotional, environmental and cultural influences, including communities' values and relations to place), we can try to delineate risks to thriving such as malnutrition, access to schools and areas of curriculum, and highlighting forms of subject-specific knowledge that exclude some groups.

- Research suggests that academic and cognitive skills gained in a variety of contexts have direct reciprocal interactions with each other and other domains during educational development, and these interactions facilitate mutual growth.

- Literacy is widely recognized as a key gateway to academic learning.

- Learning literacy and numeracy requires learning culturally invented symbol systems, the acquisition of which builds on the

To enable children to thrive across academic domains, curricula and assessment methods can be developed to acknowledge diverse ways in which children can progress through learning trajectories and demonstrate their knowledge.

development of spoken language skills and spatial skills prior to and during early school years.

- Curricula involve multiple ways of knowing. We have reported research that suggests risks to learning and indicators of what it means to thrive in the areas of science, art, music and PE, yet in less detail to literacy and numeracy.

5.6 .2

IMPLICATIONS

- Advice to governments can stress that academic skills are not universal and are culturally inflected. This might legitimate flexibility in learning systems.

- One key objective for inclusive and empowering education is to identify intertwining elements that support children's healthy cognitive and socio-emotional development from a child-centred

perspective and design educational systems that maximize equal opportunities for all children.

- Fostering early language and counting skills in a way that is tailored to cultural and inter-individual diversity will provide an essential kickstart to children's acquisition of literacy and numeracy skills.

- To enable children to thrive across academic domains, curricula and assessment methods can be developed to acknowledge diverse ways in which children can progress through learning trajectories and demonstrate their knowledge. One way forward is to develop dynamic, formative assessment to recognize the wide variations in learning trajectories.
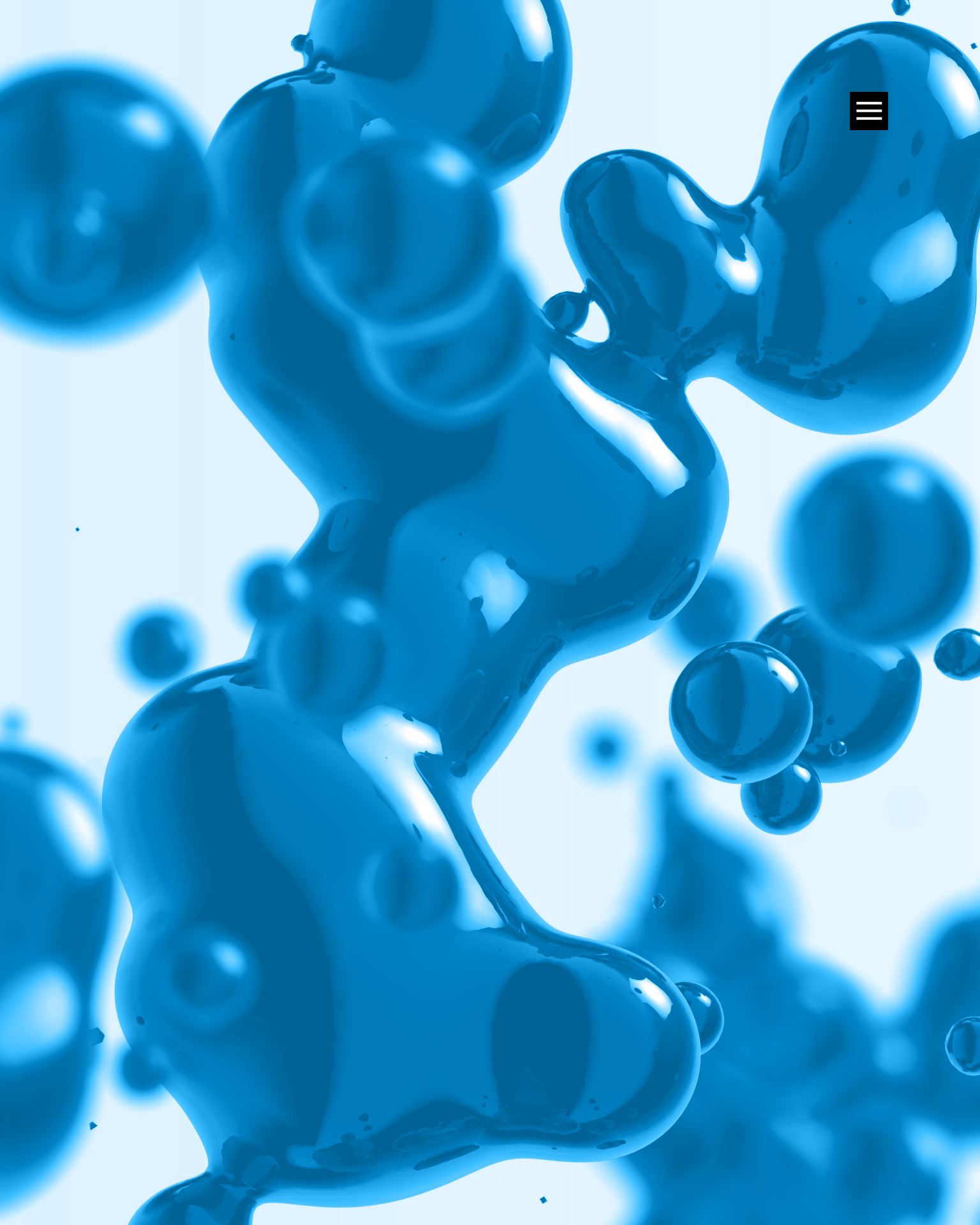
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CHAPTER

6

Identifying and supporting children with learning disabilities

This chapter should be cited as:

This chapter assesses ways to identify and support children with learning disabilities. Learning disabilities affect many students and are seldom attributable to a single cause. They arise through complex interactions between biological and environmental factors within individual developmental trajectories. Early identification of children at risk for learning disabilities as well as adequate identification of children with learning disabilities are important for ensuring that children have access to the supports they need in order to reach their full potential. Here, we discuss identifying children's learning needs and providing educational support. Although many school systems recognize the need to provide inclusive education to support all learners, more work is needed to raise awareness and enable adequate evidence based early identification of children with learning disabilities and support their learning trajectories and instructional needs inside and outside of the classroom. It is also fundamental to acknowledge the importance of research on diverse populations that could inform identification and support in various countries and socio-cultural contexts.

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6.1

What are learning disabilities, disorders and differences?

Over 1 billion people from around the world have some form of disability **(WHO, 2011)**. Around 240 million children have a disability **(UNICEF, 2021)**. Disability is diverse. Most official definitions, such as those in the World Health Organization (WHO) **(1980)**, and the United Nations (UN) Standard Rules on the Equalization of Opportunities for People with Disabilities **(UN, 1993)**, include two common features: '(i) a physical or mental characteristic labeled or perceived as an impairment or dysfunction and (ii) some personal or social limitation associated with that impairment' **(Wasserman et al., 2016)**.

Children with disabilities are less likely to attend school, and even when they do, they may be excluded from participating completely in learning to their full potential **(Filmer, 2008)**. An analysis of eighteen household surveys conducted across fifteen countries[1] on the influence of disability on school attendance reveals that disability explains a larger proportion of the gap in school attendance than other individual or household factors (e.g. socio-demographics factors, sex or residence **(Mizunoya, Mitra and Yamasaki, 2016)**. The study shows that more than 85 per cent of primary-school age children with a disability have never attended

[1]Albania, Bangladesh, Ethiopia, India, Indonesia, Malawi, Maldives, Nigeria, Papua New Guinea, Saint Lucia, South Africa, Tanzania, Uganda, Vietnam, and West Bank and Gaza

[2]Adopted by ninety-two governments and twenty-five international organizations, this statement was later reinforced by the UN Sustainable Development Goals (SDGs, specifically SDG 4 'Education', which calls upon education systems to eradicate poverty and achieve a better and more sustainable future for all by 'ensur[ing] inclusive and equitable quality education and promote lifelong learning opportunities for all' **(UNESCO, 2020)**.

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school and suggests that initial enrolment of disabled children may represent a substantive barrier to inclusion of disabled children. Even in countries having reached close to universal primary education, secondary-school enrolment rates were not correlated to inclusivity (as measured by the ratio of disabled to non-disabled out-of-school children), suggesting that new policies to improve overall attendance are not sensitive to the needs of disabled children **(Richardson, 2018)**. The vast majority of disabled children who are out-of-school live in sub-Saharan Africa, South and West Asia, the Arab States, and North Africa **(Winzer and Mazurek, 2015)**. Children with disabilities, institutionalized children, children with special educational needs, indigenous children or those from pastoral or nomadic communities, or those

who are absent from mainstream schooling are systematically excluded from data of large-scale surveys and studies, leading to their invisibility in monitoring and evaluation, and to their exclusion from evidence based research informing policy reforms in education **(Richardson and Ali, 2014)**. Moreover, many disabilities are invisible, as they affect brain and cognitive functioning, and are not immediately apparent to children's parents, teachers, and peers **(WHO, 2011)**.

The goal to give access to education to everyone has been recognized by the international community through various global initiatives such as the Salamanca Statement and Framework for Action on Special Needs Education adopted in 1994[2]. How to better attain this ambitious goal is still

highly debated in the scientific community. The definition of disability and criteria for classifying different educational needs (and qualifying for receiving them) remain contested and vary in different legal and medical systems. Importantly, classification of a child's cognitive or physical variation as an impairment 'may be statistical, based on the average in some reference groups; biological, based on a theory of human functioning; or normative, based on a view of human flourishing' **(Wasserman et al., 2016, p. 1)**. In other words, an impairment is, by definition, decided based on a comparison to some idea of what is a 'typical' or 'normal' developmental trajectory based on social, cultural and biological norms. Factors that enable or disable students are many and varied **(Bronfenbrenner, 1976; Anderson, Boyle and Deppeler, 2014)**. These factors sit within the classroom, playground and school contexts, as well as within the broader political, sociocultural and historical contexts. An example can be seen in the influence of the way societies understand and

value the entities of education and difference – the further a student's characteristics are from what is considered the norm or standard of the education system or school, the greater their determined level of disability or need **(Mac Ruairc, 2020)**. Therefore, identification of disabilities tends to focus on children's impairments or deficits, and this emphasis on impairments can lead to stigmatization and underestimation of children's potential. The concept of neurodiversity is a response to this stigmatization and emphasizes that variation in neurodevelopment leads to strengths as well as impairments to learning, and that children with disabilities are not inferior to their typically developing peers **(Saltz, 2017) (WG2-ch4** for a detailed discussion on neurodiversity). However, reframing disability in a neurodiversity context can lead to suboptimal intervention strategies and ethical dilemmas about 'who' determines 'which' students qualify for services. Here we emphasize the importance of recognizing the many complex ways in which children's education

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needs vary. Ideally, education should help each student to reach their full potential, while being mindful of the variation in individuals' potential.

Despite the acknowledgement by nations worldwide of the importance of education for all, great differences distinguish the Global North and the Global South in terms of approaches to disability.[3] Although disability and its various forms and needs have now found a legitimate place in legislative action, academic research, education programming and professional treatment in the Global North, the opposite is true in most low to middle income countries **(Winzer and Mazurek, 2015)**. In those countries, approaches to disability are slowly moving from issues of social welfare and protection to integral parts of the national development agenda and human rights agenda. However,

research on disability in low-to-middle income countries remains scarce. Studies tend to be sporadic and provide few theoretical or methodological insights to guide policy-making. Collection of data is still at an early stage in many nations, which makes globally comparable data on disability difficult to obtain **(Winzer and Mazurek, 2015)**, and there is still a critical lack of classroom based research, especially in low to middle-income countries **(Hughes and Talbott, 2017)**. For example, in the Indian context, despite its inclusive disability policies, 'there continues to be a significant lack of research examining teaching and learning processes in the classroom and debates continue to draw heavily on personal narratives, inferences drawn from Northern literature and oversimplified generalizations' **(Singal, 2014, p. 203)**.

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[3]The North–South divide (or Global North and Global South) is a political and socio-economic division of the world, popularized in the late twentieth century, roughly based on the categorization of countries by their economic and developmental status. Generally, definitions of the Global North include Australia, Canada, Israel, Japan, New Zealand, Singapore, South Korea, Taiwan, the USA and almost all European countries. The Global South is made up of Africa, Latin America and the Caribbean, Pacific Islands, and most Asian countries, including the Middle East. We recognize that this view is overly simplistic and does not reflect the complexity of global political and socio-economic realities, but a thorough discussion of these terms falls beyond the scope of this chapter.

Statistics on prevalence of learning disabilities in various age populations worldwide are extremely difficult to gather, and so are rates of children receiving support.

This chapter focuses primarily on the 'invisible disabilities': learning disabilities. Statistics on prevalence of learning disabilities in various age populations worldwide are extremely difficult to gather, and so are rates of children receiving support.

This data can be particularly vulnerable to distortion or bias for many reasons, including the absence of a precise operational definition of learning disabilities that is widely accepted, or the fact that many incidence surveys rely on self-reporting. Nonetheless, the incidence rates are considered extremely high. In the United States (USA), for example, in 2019–2020, the number of students aged three to twenty one who received special education services under the Individuals with Disabilities Education Act (IDEA) was 7.3 million, or 14 per cent of all public school students in the country. Among students receiving special education services, the most common category of disability (33 per cent) was specific

learning disabilities **(Irwin et al., 2021)**.

Early identification for many disabilities, especially learning disabilities, is challenging, because they are hidden. For example, many neurodevelopmental disorders do not present physical or sensory markers for teachers to readily identify them in the classroom. Neurodevelopmental disorders are highly prevalent in school children and encompass a broad array of, often co-occurring, disorders that 'involve impaired development of cognitive or motor functions manifest from childhood' **(Thapar and Rutter, 2015, p. 31)**. There is little consensus across different diagnostic and classification systems for what is considered a neurodevelopmental disorder, but here we will focus on specific learning disabilities (SLDs)[4], developmental language disorders and attention deficit hyperactivity disorder (ADHD). The terms 'disability', 'disorder' and 'difficulty' are sometimes used interchangeably and are a source

[4]We use the term specific learning disability in reference to impairments in reading, writing or maths as defined by the DSM.

... many neurodevelopmental disorders do not present physical or sensory markers for teachers to readily identify them in the classroom.

of contention among researchers, policy-makers and practitioners. Disorder is a medical term used by the Diagnostic and Statistical Manual of Mental Disorders V (DSM-V), which is a manual that guides mental health professionals in North America. Disability is a legal term used in the Individuals with Disabilities Education Act (IDEA) to protect the rights of students with disabilities in the USA. In the field of neurodiversity, the large variation found in human brain function leads researchers to refer to the variation that causes difficulties as a 'difference' rather than a 'disability' or 'disorder' **(Kasten, 2014)**. We are far from reaching a universal definition of a learning disability, and because diagnostic criteria and definitions vary across countries and school systems, throughout this chapter we use the term 'disability' to refer to any condition that impairs a child's ability to learn.

It is important to note that children can struggle with learning and academic outcomes due to a cascade of aetiological factors. This can include (but

is not limited to) the lack of adequate (or any) schooling, the quality of schooling, instruction in a language or orthography other than one's primarily home language/orthography, and environmental factors including stress, trauma and neighbourhood factors, as well as nutrition and sleep. Difficulties with learning that arise from these factors may not always be classified as a neurodevelopmental disorder or a learning disability but these children need access to the same interventional strategies within their educational and community settings and resources as children classified with an SLD. It is a common misconception that these children require something substantially different rather than more of the evidence based interventions that have been shown to remediate reading as well as maths difficulties. However, these additional factors may further require additional interventions to directly address the aetiological factors that can exacerbate or cause difficulties with learning and academic outcomes. Here we draw on

It is important to note that children's individual needs should be considered regardless of the aetiology of their difficulties (known or unknown) and whether they have received a diagnosis, because many learners need extra support.

evidence from education, psychology and neuroscience to explore the heterogeneity and complexity of learning disabilities and how they interact with socio-economic risk factors, such as poverty. Reviewing the evidence surrounding best educational practices across all neurodevelopmental disorders is beyond the scope of this chapter. We focus predominantly on SLDs, because they provide a useful framework for discussing the evidence surrounding best practices for screening to identify children's specific educational needs and targeting interventions to support their learning. We will also discuss evidence surrounding diagnostic practices, reliability and validity issues surrounding diagnosis, and argue that more research is needed to improve ways to identify children with SLD across cultures. It is important to note that children's individual needs should be considered regardless of the aetiology of their difficulties (known or unknown) and whether they have received a diagnosis, because many learners need extra support. There are rarely enough professionals to recognize individual children's needs

and requiring a diagnosis can also serve as a barrier to accessing support **(Ahmad, 2015)**.

6.1 .1

KEY QUESTIONS

Throughout the different sections in this chapter, we explore current knowledge and debates concerning children with learning disabilities. We take a multidisciplinary approach, synthesizing expertise based in developmental cognitive neuroscience, learning sciences, genetics and developmental psychology, with expertise based in disabilities studies, special educational needs and inclusive pedagogy. The following key questions in this chapter are addressed in sections **6.2, 6.3** and **6.4** respectively.

• Why do children with learning disabilities need extra support to succeed in school?

• How can we identify children's diverse learning needs?

• How can we support all children's learning?

6.2

Overview of reasons children may need extra support for learning

SPECIFIC LEARNING DISABILITIES

The DSM-V **(2013)** classifies SLDs as neurodevelopmental disorders. It defines neurodevelopmental disorders as 'a group of conditions with onset in the developmental period' that result in impairment in 'personal, social academic, or occupational functioning' **(DSM-V, 2013, p. 7)**. SLDs have a neurobiological aetiology and are

... in the absence of interventions, SLDs often cause psychological and functional difficulties in childhood that can last throughout the lifespan

heritable; however, behavioural/psychosocial and environmental factors can significantly influence their clinical manifestation. Exclusion criteria include intellectual impairment, sensory deficits and lack of instruction. SLD in reading is the most common type, accounting for 80 per cent of SLDs **(Snowling, 2013)**.

As indicated above, SLDs often significantly impact areas of academic function. They arise when persistent difficulties acquiring academic skills are unexpected in the context of age and grade level standards. Most common SLDs are in the areas of reading (dyslexia), mathematics (dyscalculia) and/or written expression (developmental coordination disorder or dysgraphia). Academic underachievement is not primarily due to intellectual disability, economic disparity, sensory disorders, emotional and/or motivation disturbances, or lack of instruction or inadequate quality of instruction. While interventions are not always completely successful, in the

absence of interventions, SLDs often cause psychological and functional difficulties in childhood that can last throughout the lifespan **(Klassen, Tze and Hannok, 2013)**. SLDs are often associated with other neurodevelopmental disabilities, including but not limited to ADHD, autism and developmental language disorder, as well as behavioural difficulties, psychiatric conditions and mental health problems **(Allington-Smith, 2018; Grigorenko et al., 2020)**. The aetiology (cause) of SLDs is multifaceted and differs among individuals. It can include genetic, neurodevelopmental, perceptual, cognitive and environmental factors. Dyslexia, a specific reading disability, is arguably the most understood among SLDs. We know far less about the underlying causes of dyscalculia, and even less about dysgraphia. Below we review the most recent evidence of the cognitive precursors for dyslexia, dyscalculia and dysgraphia, co-occurring conditions as well as their multidimensional profiles. Knowledge of what characterizes SLDs can improve efforts to develop effective screening tools

> The causes of poor oral language skills are multifaceted and include a language disability, the richness and quality of the language environment in the home, or being a second-language learner in the language of instruction.

DYSLEXIA AND READING DISABILITIES

Developmental dyslexia is a persistent difficulty in learning to read words, especially as it relates to poor decoding, the process by which words are sounded out through letter–sound association **(Hulme and Snowling, 2016)**. Children with dyslexia exhibit severe word reading difficulties and slow reading development relative to their peers; as they mature, their difficulties include slow and error-prone word reading and this can subsequently result in reduced reading fluency and poor text comprehension. If unaddressed, these difficulties persist into adulthood. Although early work on dyslexia sought to characterize it as a difficulty in visual processing **(Orton, 1925)**, the contemporary prevailing view is that of a multifactorial aetiology **(Pennington et al., 2012; Catts and Petscher, 2020)** and that visual factors play a minimal or no role in the aetiology. However,

one of the key deficits has been shown to be poor phonological awareness, or the ability to recognize and manipulate the phonemic structure that makes up spoken words **(Bradley and Bryant, 1978)**. Similarly, recommendations for best practices in remediation focus on employing a phonics based approach, in which children receive intensive training in letter–sound associations **(National Reading Panel, 2000)**. It is important to also note, however, that even in the case of good decoding, a lack of oral language skills (e.g. vocabulary or oral listening comprehension) can also lead to a reading disability, which is then primarily characterized by problems with reading fluency and reading comprehension **(Catts et al., 2015)**. This is illustrated by the reading rope that characterizes Scarborough's 'Reading Rope' **(2001, see Figure 2)**. The causes of poor oral language skills are multifaceted and include a language disability, the richness and quality of the language environment in the home, or being a second-language learner in the language of instruction.

THE MANY STRANDS THAT ARE WOVEN INTO SKILLED READING

LANGUAGE COMPREHENSION

BACKGROUND KNOWLEDGE
(facts, concepts, etc.)

VOCABULARY
(breadth, precision, links, etc.)

LANGUAGE STRUCTURES
(syntax, semantics, etc.)

VERBAL REASONING
(inference, metaphor, etc.)

LITERACY KNOWLEDGE
(print concepts, genres, etc.)

increasingly strategic

SKILLED READING:
Fluent execution and coordination of word recognition and text comprehension.

WORD RECOGNITION

PHONOLOGICAL AWARENESS
(syllables, phonemes, etc.)

DECODING (alphabetic principle, spelling-sound correspondences)

SIGHT RECOGNITION
(of familiar words)

increasingly automatic
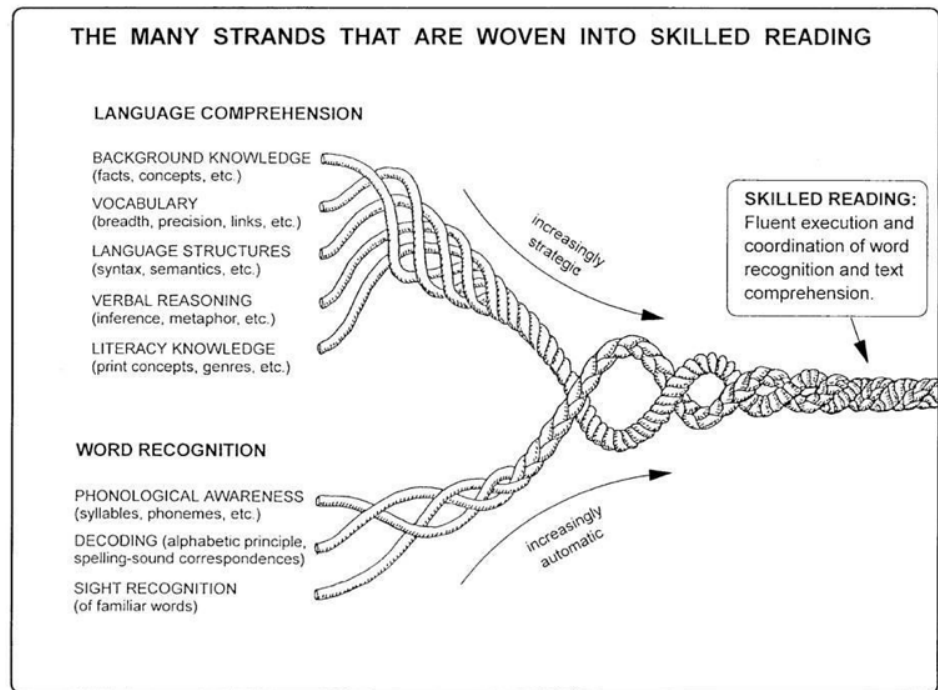
Figure 6.1. The Reading Rope, Source: Scarborough (2001)

One can summarize that children can struggle with either the 'mechanics' of reading (the word recognition aspect) or with oral language comprehension. Difficulties with language comprehension primarily affect reading comprehension but can also influence reading fluency. However, many children struggle with language comprehension and word recognition. Identifying the specific elements of reading that lead to reading difficulties in an individual child has important implications for instructional and interventional strategies.

A different and well-documented difficulty in dyslexia pertains to problems with rapid automatized naming (RAN), in which individuals are slower at retrieving and naming aloud repeated sequences of highly familiar visual stimuli such as letters **(Denckla and Rudel, 1976)**.

> It has been shown that the similarities among individuals with dyslexia who learn to read in different orthographies are much larger than their differences...

Notably, this difficulty extends to non-orthographic stimuli such as objects or colours, suggesting it does not simply reflect problems with letter recognition. Likewise, although phonological and RAN deficits can co-occur in poor readers, they are at least partially independent **(Logan, Schatzschneider and Wager, 2011)**. This has led to the double-deficit hypothesis, which explains dyslexia through the joint contribution of both phonological and rapid naming difficulties **(Wolf and Bowers, 1999)**.

Languages' writing systems vary significantly with respect to spelling-sound regularity. For instance, Italian and Finnish map letters to phonemes on a near 1:1 basis, whereas English or French have much lower levels of consistency **(Ziegler et al., 2010)**. At the other extreme, logographic systems like Chinese code words as one or two symbols, featuring much less consistency in spelling-sound mapping. This raises the question whether different cognitive processes underlie reading cross-culturally, and also whether dyslexia is a culturally-specific phenomenon.

On both counts there is strong evidence supporting a unified model cross-linguistically. It has been shown that the similarities among individuals with dyslexia who learn to read in different orthographies are much larger than their differences with the common overlaps primarily shown for RAN deficits as well as phonological decoding mechanisms **(Ziegeler et al., 2010)**. The core neurocognitive mechanisms engaged during skilled reading appear to be universally constrained such that the brain signatures of reading are similar irrespective of orthographic structure **(Rueckl et al., 2015)**. Similarly, while behavioural manifestations of dyslexia may vary subtly across languages **(Ziegler and Goswami, 2005)**, these seem to reflect the characteristics of the writing system rather than different underlying causes. It is important to note that the high rate of co-occurrence with other disorders supports a generally inclusive view of reading disorders, rather than one in which poor reading is only considered meaningful if it

occurs in isolation. The scientific literature has begun to reflect this important nuance by categorizing affected children as having a 'reading disability', and also using more criteria that do preclude children with co-occurring SLDs **(Elliott and Gibbs, 2009)**.

| 6.2 | .1 | .2 |

DYSCALCULIA AND MATHS DISABILITIES

Developmental dyscalculia is characterized by persistent difficulties in processing numerical information and acquiring simple arithmetic skills **(Iuculano, 2016)**. Individuals with dyscalculia can present deficits at the level of basic numerical abilities (i.e. correctly identifying the number of items in a set), or in symbol recognition and transcoding (i.e. knowing that the symbol '3' is associated with the quantity of 'three'). In less severe cases, individuals may not experience basic numerical difficulties, but still struggle with their arithmetical computations or retrieval processes (i.e. solving

– or remembering – the result of operations such as '3 + 5 = ?').

To date, we know far less about the manifestations of dyscalculia relative to what we know about dyslexia. One proposal suggests that dyscalculia arises from a core deficit in processing non-symbolic quantities (e.g. a collection of items) **(Butterworth, 2010; Piazza et al., 2010; Reigosa-Crespo et al., 2012)**. In line with this proposal, individuals with dyscalculia have been reported with neural aberrancies in brain regions that are known to be involved in detecting changes in the quantity of items within a set **(Price et al., 2007)**. These brain regions are part of the parietal cortex, located just above our ears. Yet, not all children with dyscalculia show poor performance on non-symbolic quantity tasks relative to typically developing controls **(Rousselle and Noël, 2007; De Smedt and Gilmore, 2013; Bugden and Ansari, 2016)** suggesting different routes to the disorder. An alternative proposal suggests that dyscalculia may be the result of a deficit in

dyscalculia can result from one (or multiple) cognitive and neural aberrancies at any level of the hierarchical cascade of processes that, sequentially, supports the successful acquisition of formal mathematical knowledge over development.

Another crucial step in the successful acquisition of mathematical knowledge is the ability to retrieve the result of an arithmetical operation directly from memory.

mapping number symbols (e.g. '3') to their appropriate meanings (e.g. the quantity of 'three') **(Rousselle and Noël, 2007; De Smedt and Gilmore, 2011)**, an ability that has been extensively associated with arithmetic learning **(Xenidou-Dervou et al., 2017)**. A more recent and pervasive view – which can help reconcile these theoretical accounts – is that dyscalculia is characterized by multiple deficits **(Rubinsten and Orly, 2011; Fias, Menon and Szucs, 2013; Bartelet et al., 2014; Iuculano, 2016; Skagerlund and Träff, 2016; Träff et al., 2017; Peters and Ansari, 2019)**. In other words, dyscalculia can result from one (or multiple) cognitive and neural aberrancies at any level of the hierarchical cascade of processes that, sequentially, supports the successful acquisition of formal mathematical knowledge over development. Notably, the discipline of formal mathematics goes beyond the mere comparison of quantities, or transcoding abilities. For example, even learning how to add symbolic quantities together (e.g. '3 + 8') requires a class of complex cognitive functions such as the ability to apply rules and – at

least initially – the ability to hold and update intermediate results temporarily. The latter is called working memory and is supported by an efficient crosstalk between regions of the parietal cortex and regions of the prefrontal cortex – in the front of our brain. Critically, children with dyscalculia are often reported with working memory deficits **(Iuculano, Moro and Butterworth, 2011)**, and aberrant connections between these two brain areas have been recently documented in this population **(Jolles et al., 2015)**.

Another crucial step in the successful acquisition of mathematical knowledge is the ability to retrieve the result of an arithmetical operation directly from memory. More specifically, during effective learning, and after many repetitions of practising an arithmetic problem (e.g. '3+5'), an association is slowly made between the correct solution '8' and its addends ('3' and '5') **(Siegler and Shrager, 1984)**. This is aided by another memory system residing in a small, curved

formation in the brain called the hippocampus. Critically, children with dyscalculia can often display marked deficits in remembering arithmetical facts **(Geary, 2011)**, and anomalies in the hippocampus have been recently observed in these children **(De Smedt, Holloway and Ansari, 2011)**.

Altogether, this evidence suggests that the aetiology of dyscalculia can be very heterogeneous – reflecting the hierarchical nature of the discipline of mathematics itself, wherein the next ability to be learned depends on the previously acquired one. A 'disruption' at any (or multiple) level(s) of this cascade of mental computations can lead to dyscalculia, with the most severe cases characterized by perturbation(s) at the level of core systems of knowledge. Being able to identify at which level 'disruption(s)' occur is critical for appropriate diagnosis and for targeting interventions.

Developmental dysgraphia is a SLD characterized by persistent difficulties in acquiring handwriting, spelling skills or both, despite adequate schooling.

6.2	.1	.3

DYSGRAPHIA

Developmental dysgraphia is a SLD characterized by persistent difficulties in acquiring handwriting, spelling skills or both, despite adequate schooling **(McCloskey and Rapp, 2017)**. Relative to research conducted in the areas of maths and reading, the cognitive and neural manifestations of dysgraphia are less understood. Some research shows that there is considerable overlap in dyslexia and dysgraphia such that children with dysgraphia may also experience phonological processing deficits **(Moll et al., 2009; Moll, Wallner and Landerl, 2012; Döhla and Heim, 2015)**. However, many students with developmental dysgraphia have strong phonological processing, which demonstrates that multiple impairments can lead to dysgraphia **(McCloskey and Rapp, 2017)**. Students with dysgraphia struggle with the sound-to-spelling conversion process and this could be due to difficulties with orthographic working

> ... learning difficulties are complex and heterogeneous in nature, often overlap, and ... the origin of learning difficulties therefore cannot be traced back to a single genetic, neural or cognitive cause.

memory or orthographic long-term memory. Motor control impairments or difficulties with visual memory can also underlie dysgraphia. More research is needed to better understand the acquisition of cognitive writing mechanisms and the deficits underlying developmental writing impairments (**McCloskey and Rapp, 2017**).

6.2 .2

AETIOLOGIES AND THE MULTIPLE DEFICIT MODEL

In the past, researchers studying learning disabilities, including dyslexia and dyscalculia, have searched for a single cause. For example, phonological processing deficits have long been considered to lie at the root of reading difficulties. However, not all children with dyslexia have phonological deficits, and not all children with phonological deficits are poor readers (**Snowling, 2008;**

Pennington et al., 2012; Van Der Leij et al., 2013; Catts and Petscher, 2020). Hence, a search for single deficits appears no longer tenable. It is becoming increasingly clear that learning difficulties are complex and heterogeneous in nature, often overlap, and that the origin of learning difficulties therefore cannot be traced back to a single genetic, neural or cognitive cause. Hence, the field is changing from single to multiple factorial influences.

A useful framework to investigate the aetiology of learning disabilities is the (intergenerational) multiple deficit model (**Pennington, 2006; van Bergen, van der Leij and de Jong, 2014**), depicted in **Figure 6.2**. According to this model, there is no one answer to a question like 'what causes dyslexia?'. Rather, such a question can be answered at each level of analysis (environment, genes, brain, cognition), with at each level a multitude of factors that each contribute probabilistically to a risk of developing dyslexia. The relative importance of genetic and environmental influences

Genetic studies show that, rather than one gene of big effect, there are many, probably thousands of genetic variants each influencing educational skills.

can be studied using twins **(see WG3-ch3** for a discussion on twin studies). Twin studies have shown that both individual differences in reading and maths are substantially due to genetic differences. That is, these skills are substantially heritable, with estimates for (word-level) reading around 70 per cent and for maths around 60 per cent **(de Zeeuw et al., 2015)**. In other words, 70 per cent of the differences among children in how well they read are due to genetic differences. Note that heritability estimates depend on the context of the studied populations; the heritability is higher in equalitarian and standardized educational systems, like in the Netherlands, compared to Florida, in the USA **(van Bergen et al., 2018; Daucourt et al., 2020b)**. From a genetic and environmental perspective, reading and maths are very similar, with overlapping sets of genetic influences and overlapping influences in the home and school environment **(Daucourt et al., 2020a)**.

Genetic studies show that, rather than one gene of big effect, there

are many, probably thousands of genetic variants each influencing educational skills **(Lee et al., 2018; Gialluisi et al., 2020)**. Studies that measure children's learning environments have also shown many correlates of reading and maths achievement **(van Bergen et al., 2017; Liu, Georgiou and Manolitsis, 2018; Purpura et al., 2020)**. The fact that learning environments, especially in the home, are not independent but correlated with one's genetic influences, makes this a challenging research area, because environmental correlates cannot be interpreted as causal influences **(Hart, Little and van Bergen, 2019)**. Taken together, consistent with the (intergenerational) multiple deficit model, reading, maths and their associated disabilities are influenced by many genetic and environmental factors.

At the brain level, research has revealed that learning disabilities are heterogeneous and cannot be reduced to core deficits **(Astle and Fletcher-Watson, 2020; Siugzdaite et al., 2020)**. Both reading and maths rely on complex networks of brain areas, and differences in these
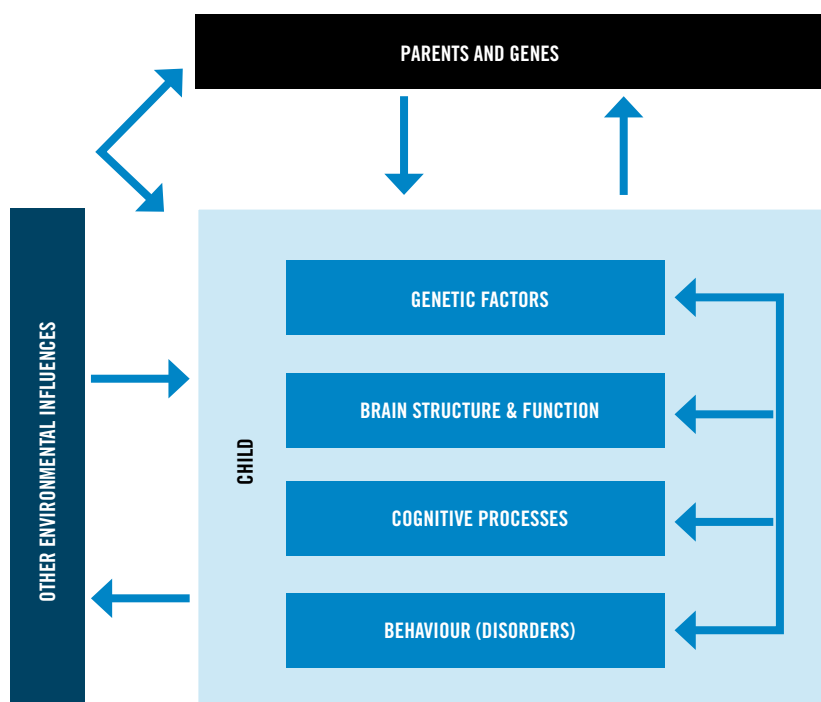
Figure 6.2. The Intergenerational Multiple Deficit Model of Developmental Disorders Source: Adapted from van Bergen et al. (2014).

networks have been identified in children with learning disabilities **(Dehaene, 2010; Peters and De Smedt, 2018)**. However, it has become clear from recent neuroimaging studies that there is no one-to-one mapping between neural profiles and behavioural difficulties **(Astle, Bathelt and Holmes, 2019; Siugzdaite et al., 2020)**. Children with the same learning disabilities do not all have similar neural profiles, and children with similar neural profiles are not all characterized by similar learning disabilities. Additionally, there appears to be substantial overlap between children with various learning disabilities at the level of the brain. Neuroimaging studies using different methods of analysis have shown that children with dyslexia and children with dyscalculia show remarkable similarity in brain activation in the context of maths and reading tasks, and in brain anatomy **(Peters et al., 2018; Moreau et al., 2019)**. These sources of

... children with learning disabilities form a somewhat heterogeneous group, because different profiles of strengths and weaknesses can lead to the same behavioural difficulties.

evidence make it clear that many neural factors influence children's learning abilities.

Finally, and as noted above, the profiles of children with learning disabilities cannot be traced back to single, cognitive origins. Clusters of different cognitive profiles have, for example, been reported in a group of children with maths difficulties **(Bartelet et al., 2014)**. This demonstrates that maths performance is influenced by more than the most commonly studied cognitive correlate, that is, numerical magnitude processing **(Butterworth et al., 2011)**. Rather, a variety of cognitive correlates has been found to be associated with reading and maths difficulties, such as processing speed, working memory and attention **(Lee and Bull, 2016; Peterson et al., 2017; Daucourt et al., 2020a)**. Some of these cognitive correlates appear to be shared between reading and maths disabilities and could therefore help clarify the high rates of comorbidity. It is becoming increasingly clear that (an interplay of) various cognitive factors influence children's learning abilities.

Together, it follows from the (intergenerational) multiple deficit model and the evidence presented here that children with learning disabilities form a somewhat heterogeneous group, because different profiles of strengths and weaknesses can lead to the same behavioural difficulties. Hence, not all children with dyslexia or dyscalculia are the same.

6.2 **.3**

CO-OCCURING CONDITIONS

Children with learning disabilities often have co-occurring neurodevelopmental, psychiatric or mental health disorders. For example, many children struggle with both mathematics and literacy learning **(Landerl and Moll, 2010; Peters, de Beeck and De Smedt, 2020)**, which is unsurprising given that achievement in these academic domains is overlapping **(Moll et al., 2016)**. Amongst children with a diagnosed mathematical

learning disability, approximately 25 per cent also have a language disability, 18 per cent have ADHD and as many as 70 per cent also have dyslexia **(McGrath, Peterson and Pennington, 2020)**. Dyslexia also often co-occurs with a language impairment **(Bishop and Snowling, 2004)** and ADHD **(Boada, Wilcutt and Pennington, 2012)**. Children with learning disabilities also have more anxiety symptoms on average when compared to children without learning disabilities **(Nelson and Harwood, 2010)**. Relatedly, individuals with co-occurring learning disabilities have lower school achievement and mental health than those identified with a single impairment **(Martínez and Semrud-Clikeman, 2004)**. There is evidence of increased co-occurrence of learning disabilities as children develop, with accumulated cognitive challenges **(Costa, Edwards and Hooper, 2016)**. In other words, children with an identified neurodevelopmental disorder may be at risk for developing co-occurring conditions due to behavioural, neuropsychological and genetic overlap. For example, the majority

of children with autism spectrum disorder (ASD) (31−95 per cent) also have symptoms of ADHD, and there is also overlap between ASD and intellectual disability **(Grigorenko et al., 2020)**. Similar to SLDs, autism cannot be traced back to single genetic, neural or cognitive causes. Moreover, genetic research has also shown that it is not straightforward to predict risk for co-occurring disorders from genetic data **(Brki et al., 2020)**. Autism has evolved from a narrow definition of a rare neurodevelopmental disorder to a complex, multi-dimensional view that recognizes a neurodiversity perspective **(Happé and Frith, 2020)**. Autism is much more prevalent than previously believed, with some estimates as high as one in 100 **(Happé and Frith, 2020)**. Many of the behaviours that are characteristic of autism are also seen in children with severe learning disabilities **(O'Brien and Pearson, 2004)**. There is also substantial overlap between children with a SLD and ADHD, and approximately 40 per cent of children who have an SLD also have ADHD **(DuPaul, Gormley**

> Autism has evolved from a narrow definition of a rare neurodevelopmental disorder to a complex, multi-dimensional view that recognizes a neurodiversity perspective.

... mental health struggles often present differently in children with disabilities and so may not be recognized until later in adolescence.

and Laracy, 2013). ADHD is a very heterogeneous condition, which is why most children with ADHD have co-occurring disorders, including anxiety and depressive disorders (Gnanavel et al., 2019). Children with ADHD tend to have lower levels of academic achievement compared to their typically developing peers and often struggle with motivation, study skills and other behaviours that are important for academic success (Rogers et al., 2015).

Children with learning disabilities are at greater risk for developing a diagnosable mental health disorder compared to their typically developing peers (Coughlan, 2011). However, mental health struggles often present differently in children with disabilities and so may not be recognized until later in adolescence (Coughlan, 2011). Moreover, teachers are often not given adequate guidance on how to identify and support the mental health needs of their students (Rose et al., 2009). Approximately 10–20 per cent of children and adolescents worldwide have mental health problems (Kieling et al., 2011). The consistency of this estimate throughout the last forty years is a striking result considering that significant inter-study heterogeneity exists. A recent meta-analysis of forty-one studies conducted in twenty-seven countries (between 1985 to 2012) estimated a worldwide prevalence of any mental disorder in children and adolescents of 13.4 per cent (Polanczyk et al., 2015). According to this meta-analysis, approximately 241 million youths around the world were affected by a mental disorder in 2015. The most common group of mental disorders were: anxiety disorders, affecting 117 million; disruptive behaviour disorder, affecting 113 million; ADHD, affecting 63 million; and depressive disorders, affecting 47 million. Interestingly, the variability of prevalence estimates was not explained by geographic location of studies and year of data collection.
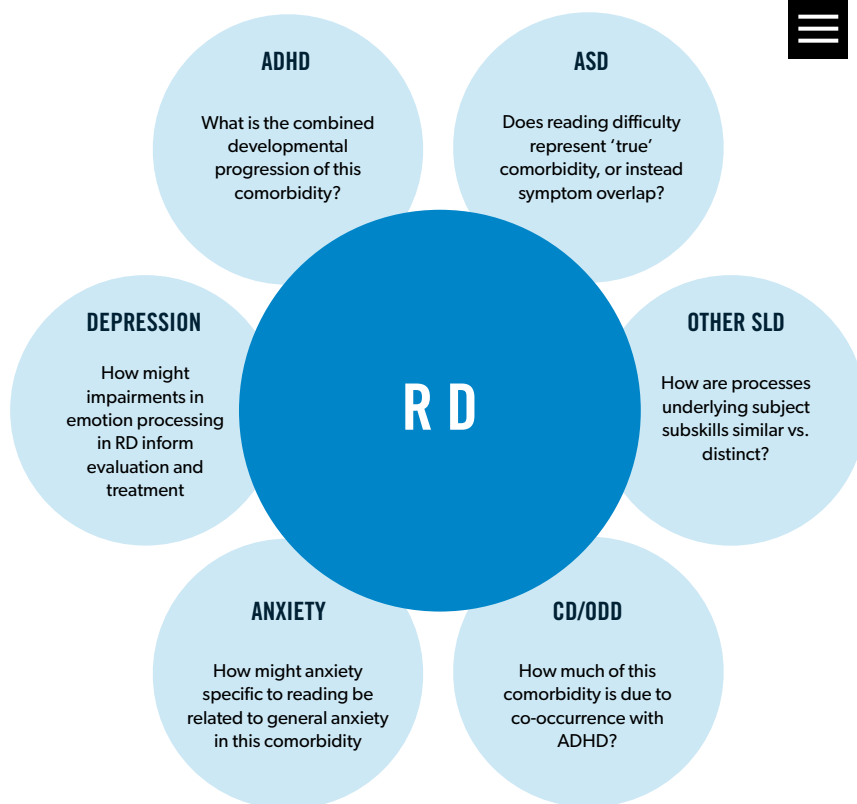
Figure 6.3. Current issues, areas of investigation, and suggestions for future research in conditions commonly occurring with RD in children. RD, reading disorder; ADHD, attention deficit hyperactivity disorder; ASD, autism spectrum disorder; SLD, specific learning disorder; CD, conduct disorder; ODD, oppositional defiant disorder.

Source: Hendren et al. (2018)

6.2 .4

VULNERABLE POPULATIONS: RELATIONSHIP BETWEEN DISABILITY, POVERTY AND EDUCATION

As already indicated at the beginning of this chapter, there are many other reasons why people struggle to learn and flourish in their daily lives. For example, there is growing evidence revealing complex relationships among disability, poverty and levels of education **(Singal, 2017)**. The Department for International Development **(DFID, 2000)** describes this relationship as cyclical in nature, stating that disability is both a cause and a consequence of poverty. According to large-scale

6

... there is growing evidence revealing complex relationships among disability, poverty and levels of education.

analyses and reviews of cross-country data from low-to-middle income countries, disability is significantly associated with higher multidimensional poverty, lower employment rates and lower educational attainment **(Groce et al., 2011; Mitra, Posarac and Vick, 2013; Winzer and Mazurek, 2015)**. The reverse is also true such that lack of educational attainment is a key factor in predicting poverty during adulthood for people with disabilities **(Groce et al., 2011; Mitra, Posarac and Vick, 2013; Winzer and Mazurek, 2015)**. For instance, it has been shown that literacy is associated with many indices of academic, social, vocational and economic success and is a widely recognized determinant of health **(Irwin, Siddiqui and Hertzman, 2007)**. Furthermore, the duration of education, which is highly dependent on academic success and especially reading proficiency, has been considered to be an important predictor of health and longevity. Winzer and Mazurek **(2015, p.161)** have summarized this: 'When school enrolment is restricted, curtailed, or simply denied, it often marks the beginning of a lifetime of exclusion from mainstream society for persons with disabilities and means that they are more likely to remain poor'.

Owing to systematic exclusion from basic health care services, political and legal processes, and education and employment, people with disabilities are likely to have significantly reduced income-generating opportunities, leading to poverty **(Mitra, Posarac and Vick, 2013)**. In turn, poverty can deeply hamper the learning process and limit accessibility to education **(Winzer and Mazurek, 2015; WG2-ch4)**, particularly when parents are unemployed, or are illiterate, and consequently struggle to support the learning of their children **(Nel and Grosser, 2016)**. In areas of poverty there is usually a higher incidence of physical and emotional stress (e.g. violence, sexual abuse) that may affect learners so severely that they lose their ability to fully take part in the learning process or could lead to absenteeism from school, and eventually dropping-out **(Peterson and Hittie, 2003)**.

Nevertheless, it is important to re-emphasize that all children who struggle with learning need access to instructional and interventional strategies to maximize their potential and joy of learning regardless of the aetiology of their struggles, their diagnostic status and other factors influencing their learning struggles **(WG3-ch5)**.

Similarly, being poor increases one's probability of acquiring an impairment due to limited access to health care, poor sanitation facilities, lack of basic services, low nutritional intake and increased risks of living in hazardous conditions, among others **(DFID, 2000; Nel and Grosser, 2016)**. These factors can contribute directly and indirectly (through the mother, if they impact pregnancy or birth) to physical and mental impairments, such as mobility deficits and intellectual, behavioural, learning and cognitive disabilities **(UNICEF, 2013)**. Specifically, poverty is one of the greatest environmental risk factors for learning difficulties

(UNESCO Institute for Lifelong Learning, 2021; Winzer and Mazurek, 2015; WG2-ch4). Disability prevalence rates are much higher in the Global South as compared to the Global North **(Winzer and Mazurek, 2015)**.

Not only can disability and poverty influence access to schooling **(WG2-ch4)**, but they are also likely to shape the learner's experience in the classroom. Although the low quality of education and lack of learning of children with disabilities has been observed in many cultural contexts, the underlying reasons may strongly differ between countries. Learning disabilities, along with other physical or cognitive impairments such as neurological disabilities (e.g. cerebral palsy), sensory barriers (e.g. hearing loss or visual impairments), epilepsy, physical impairments, communication disorders, attention, distractibility and memory problems, and chronic health impairments can threaten academic success. Other medical problems at birth, such

> ... poverty is one of the greatest environmental risk factors for learning difficulties.

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[5]Absence or deficiency of oxygen reaching the tissues, and particularly the brain.

as premature births, anoxia,[5] and damage to the brain after birth because of head injuries caused by accidents, or child abuse and illness, could also contribute to learning disabilities **(Nel and Grosser, 2016)**. Apart from the difficulties directly related to the disability itself, which are relatively similar across cultures, other complex sociocultural factors may hinder the learning process. In India for example, large classroom based studies point to a lack of teacher expertise and confidence in meeting the needs of children with disabilities **(Singal, 2017)**. Similar results have been found in South Africa **(Engelbrecht, 2003)**. A lack of international large-scale studies and international

comparable data makes it difficult to draw clear and general conclusions. Because scientific knowledge and theoretical models mainly developed in the Global North often shape policy and educational practices for students with disabilities and learning difficulties in completely different cultural contexts, several authors underscore the risks of applying such knowledge without allowing for a thorough analysis of the disability context of particular countries, of how disability and learning difficulties are perceived in that country, and without seeking to build upon successful local ways of working with people with disabilities see for example **(Kalyanpur, 2014 and Maudslay,**

> A lack of international large-scale studies and international comparable data makes it difficult to draw clear and general conclusions.

BOX 1. NEURODISABILITY

2014 discuss in the Nepali and Cambodian contexts, respectively).

Neurodisability (i.e. the deficits or impairments that an individual can experience when they have been affected

by a brain injury) is highly prevalent and often neglected in education settings, especially in poorer and more vulnerable populations. One cause of ND is acquired brain injury, which can involve injury (e.g. from a fall or road accident),

> ... the most disadvantaged 5 per cent of children under five years of age in the United Kingdom (UK) are five times more likely to have a TBI compared to their peers.

infection (e.g. herpes simplex) or illness of the brain (e.g. stroke). Traumatic brain injury (TBI) is the most common form, and is the leading cause of death and disability in those under forty years of age. TBI can result in significant ongoing difficulties, which have been associated with adverse life outcomes such as substance abuse, self-injurious behaviour and entrance into the criminal justice system **(Gunter et al., 2013; McKinlay et al., 2014)**. The peaks in prevalence are during infancy (zero to five years of age), and during adolescence, with a worldwide incidence of forty-seven to 280 per 100,000 children **(Dewan et al., 2016)**. Of critical importance is the large social divide in this epidemic: the most disadvantaged 5 per cent of children under five years of age in the United Kingdom (UK) are five times more likely to have a TBI compared to their peers **(Chris Bryant, MP, Hansard, 2019)**. Though TBI is thought to affect approximately 8–12 per cent of the population, it is not routinely

assessed and recognized by the education system, with children misinterpreted as 'difficult'. It is of no surprise that children are therefore struggling to adequately and fairly access education, limiting future prospects **(Silver et al., 2001; Frost et al., 2013; Kahn et al., 2018)**.

Considered an 'invisible disability' owing to children's purported physical recovery after most TBIs, the consequences of the injury are often unidentified and misdiagnosed **(Glang et al., 2019)**. There is a clear risk that later in life the effects of injury are forgotten or considered insignificant. Cognitive and behavioural difficulties often occur after TBI and lead to poorer outcomes in adulthood **(Di Battista et al., 2012)**. These difficulties have been linked to measurable and lasting damage to the brain **(Roberts, Mathias and Rose, 2016)**. Impulsivity, attentional problems, reactive aggression and issues with behavioural or emotional regulation are common

... childhood TBI mediates the relationship between poor educational attainment and offending behaviour in adolescents.

problems following TBI **(Pastore et al., 2018; Williams et al., 2018)**. In cases of severe TBI, theory of mind (ToM) is often affected (the ability to put oneself 'in another's shoes', and understand how others may think, feel and act in a manner different from our own experiences) **(Hoskinson et al., 2019)**. Poorer cognitive and affective ToM are predictive of higher levels of reactive aggression in childhood **(Austin, Bondu and Elsner, 2017)**. These are issues that could interfere with classroom behaviour and contribute to school exclusion, as well as peer relationships and mental health **(Yeates et al., 2013; Lantagne et al., 2018)**.

TBI is a pervasive factor impacting educational attainment. Structural equation modelling has shown that childhood TBI mediates the relationship between poor educational attainment and offending behaviour in adolescents, showing the significance of addressing TBI related-needs earlier in the education system **(Clasby et al., 2020)**. Parenting practices can influence outcomes following childhood TBI, and poor parental supervision is associated with both more severe TBI and higher levels of reactive aggression in young offenders **(Kent et al., 2021)**. TBI can exacerbate existing difficulties with maturity and social development, and greatly reduce an individual's ability to cope with, and adapt to, the social and academic pressures of school **(Williams et al., 2020)**. In school, these difficulties are often labelled as oppositional or defiant behaviour, and when classroom resources are stretched poor motivation and withdrawal can be easily overlooked **(Lantagne et al., 2018; UKABIF, 2018)**. The British Psychological Society has called for the earlier screening of children to identify TBI – for example at the point of exclusion from school **(British Psychological Society, 2015)**. Systemic school based screening for neurodisability – including TBI – using tools such as the Clasby Neurodiversity Assessment Tool (CNAT), paves the way

Systemic school-based screening for neurodisability - including TBI - paves the way for appropriate support being provided and the subsequent introduction of TBI-specific educational interventions.

for appropriate support being provided and the subsequent introduction of TBI-specific educational interventions.

TBI in infancy and childhood is associated with more severe long-term neurocognitive and psychosocial outcomes than TBI sustained in late adolescence. The worst outcomes of TBI in adolescents are associated with both more severe injuries and delay in assessment and intervention **(Di Battista et al., 2012)**. Childhood is a period of rapid, protracted brain development and TBI interferes with the emergence of rapidly developing skills and magnifies any deficits later in life **(Gogtay et al., 2004; Donders and Warschausky, 2007)**. Mild TBI is also an important trans-diagnostic risk factor associated with developmental patterns of psychopathology in children and adolescents **(McCormick, Connolly and Nelson, 2020)**.

Children with TBI are vastly underidentified in schools and education services. A study conducted in the USA in 2019 identified that an estimated 145,000 children and adolescents in the USA are living with long-lasting and significant difficulties with behavioural, physical, social and cognitive functioning following a TBI. However, only 26,371 students receive special education services for TBI currently. Therefore, a significant number of children and adolescents with ongoing disability resulting from TBI are unidentified in the education system, and not receiving proper support **(Nagele et al., 2019)**. Education offers a global possibility to implement early, targeted interventions so that children with TBI are supported and not left out of opportunities to secure positive life outcomes.
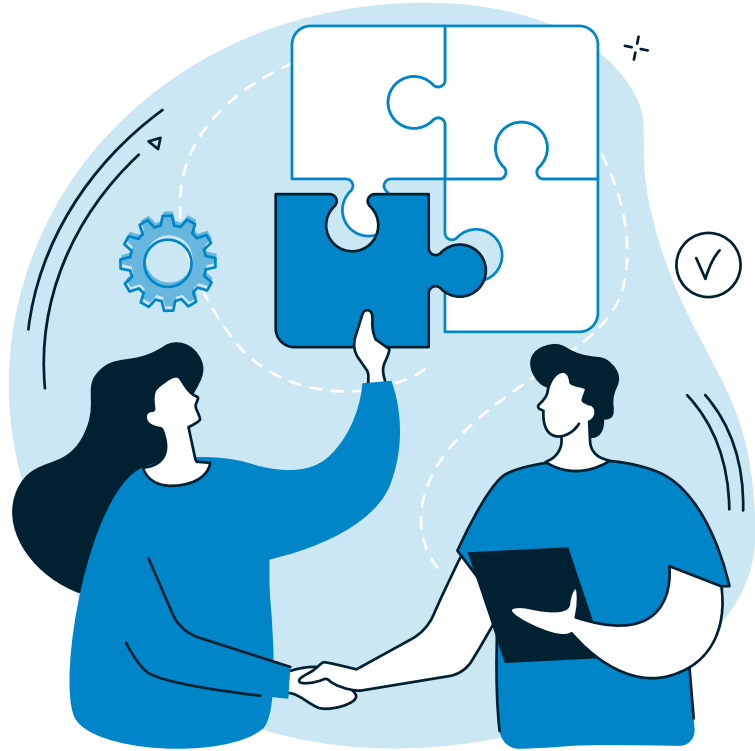
6.3

How can we identify children who need extra learning support?

6.3 .1

DIAGNOSIS OF SPECIFIC LEARNING DISABILITIES

Establishing universal criteria to identify children with SLDs is historically one of the most controversial issues among researchers and practitioners **(Harrison and Holmes, 2012)**. Some of the challenges arise from the heterogeneity and high co-occurrence of SLD with other neurodevelopmental disorders, arbitrariness associated with applying cut-offs along a continuous measure of

achievement, as well as federal and local legislature (or lack thereof) guiding definitions or 'cut-off criteria' of SLDs. Multiple methods for conceptualizing and operationalizing significant academic underachievement based on individual's age and development have emerged.

The Intelligence–Achievement discrepancy model is an approach to conceptualize the unexpected underachievement and general cognitive abilities associated with SLDs. By this method, in order to be considered to have a learning disability, the individual must have a significant difference, or discrepancy, between their IQ and achievement test score. This strategy of identifying SLDs is considered archaic and inappropriate. Although the discrepancy definition historically has been a part of an assessment of learning differences, the inclusion of a measure of intelligence is not supported by research and has excluded individuals from being identified as having a learning difference who have, in fact, had reading difficulties. **(For a review of the evidence see Fletcher, 1992;**

Siegel, 1988, 1992). There is little evidence that poor readers with low intellectual achievement show qualitatively different patterns of reading difficulties **(Stanovich, 2005)**. Similarly, children with maths learning disabilities showed poor performance on measures of numerical magnitude processing independent of IQ **(Brankaer, Ghesquière and De Smedt, 2014)**. Intelligence tests are generally very heavily loaded on language measures, now understood to be a common weakness for individuals with dyslexia **(Siegel and Ryan, 1984)**. As a result, individuals with dyslexia are more likely to have their intellectual functioning underestimated. Children with dyslexia are equally likely to respond to intervention irrespective of whether they have co-occurring intellectual difficulties and it is important to note that these interventions can benefit any child struggling with word reading regardless of the underlying aetiology **(Hurford et al., 1994; Shaywitz, 1996; Pogorzelski and Wheldall, 2002; Weber, Marx and Schneider, 2002)**. Moreover, a number of studies have reported giftedness in children with SLD

(van Viersen et al., 2016; Toffalini, Giofrè and Cornoldi, 2017), and these students may be more challenging to identify as they may be more able to compensate for their learning difficulties compared to peers with lower IQ. Despite the long history of evidence demonstrating that the IQ-discrepancy is unreliable at identifying SLDs, a recent study found that approximately 37 per cent of sampled school psychologists across the USA are still using this approach (Benson et al., 2020). There is no evidence to support the use of IQ for identifying children with SLD who need extra support in the classroom,

Another approach used to identify SLDs is the patterns and strengths model. In this method, an assessment for dyslexia or other SLDs often includes a number of tests of cognitive processes, for example, verbal comprehension, fluid reasoning (a cognitive ability that requires minimal prior knowledge to solve novel tasks), visual processing, processing speed, working memory, visual-spatial thinking, auditory

processing, and so on. These tests are designed to examine aspects of cognitive functioning and identify patterns in strengths and weaknesses in the individual being assessed. There are several forms of the patterns of strengths and weaknesses model (Naglieri, 1999; Hale and Fiorello, 2004; Flanagan, Ortiz and Alfonso, 2007). One of the main assumptions of the patterns of strengths and weaknesses models is that the performance of individuals with learning disabilities will differ from that of typically achieving individuals. Yet, this difference between performance of students with and without learning disabilities is not always found, and there is great intra-group variability using patterns of strengths and weaknesses analysis. Therefore, their diagnostic utility and validity has been questioned by several authors (Miciak et al., 2015; McGill and Busse, 2017; Benson et al., 2018). Most importantly, a particular cognitive profile of strengths and weaknesses does not predict who will benefit from remediation (Miciak et al., 2016) or what particular intervention strategy

> **… a particular cognitive profile of strengths and weaknesses does not predict who will benefit from remediation or what particular intervention strategy should be**

should be employed. These should not be considered when making diagnostic decisions **(Vaughn et al., 2008; Restori et al., 2009).**

Identification of SLDs is generally achieved using cut-off scores based on falling significantly below expected level on one or more measures of achievement. However, because the impairment is quantitative in nature, there is no broad consensus about the degree of impairment necessary for diagnosis. Generally, we observe cut-off scores one to two standard deviations below the expected mean, roughly corresponding to the third to fifteenth percentile. That said, choice in cut-off scores is largely arbitrary. Dyslexia is typically identified during the primary school years, via a psychometric evaluation that includes measures of phonological processing, letter sound knowledge, single-word reading and spelling, reading comprehension, and oral language skills. Dyscalculia is often identified using measures of arithmetic fluency and calculation performance. Although recent studies have

suggested that assessing basic numeracy skills **(Jordan, Glenn and McGhie-Richmond, 2010; Merkley and Ansari, 2016; Bugden, Szkudlarek and Brannon, 2021)** can improve the efficiency for early classification of maths learning disabilities, more work is needed to identify reliable assessment tools to identify dyscalculia.

6.3 .2

BEST PRACTICES IN EARLY SCREENING AND INTERVENTION FOR SLDS AND OTHER INDIVIDUALS AT RISK FOR POOR EDUCATION

6.3 .2 .1

IMPORTANT CONSIDERATIONS FOR SCREENING AND IDENTIFICATION

Screening practices are ubiquitous in education in the Global North as part of a preventive

Screening is the first step in supporting vulnerable populations...

systems approach to the early identification of individuals who are at risk for poor education outcomes. Screening is the first step in supporting vulnerable populations, not only to identify learners who need additional educational supports, but to subsequently provide direct, explicit instruction and intervention to improve lifelong trajectories of human flourishing. Conventional screening processes in education systems in the Global North are typically brief, reliable and valid assessments that are administered to whole classrooms of students. Performance on screeners is then compared to criteria that typically classify students into one of three groups: (1) those who are low risk (typically >80 per cent chance of meeting an expected threshold of performance on a later assessment); (2) those who are at a moderate level of risk (typically 50 per cent chance of meeting an expected threshold of performance on a later assessment); and (3) those who are at a high level of risk (typically <20 per cent chance of meeting an expected

threshold of performance on a later assessment). The diversity of available screeners for reading, maths, behaviour and other educational or social-emotional outcomes necessitates a detailing of both the core considerations one should take stock of when choosing a screener as well as the barriers, access and equity issues related to using screeners.

Choosing a screener. A particular burden on those using screeners is the decision-making of what supports to provide to individuals once scores are obtained. What should be considered during the selection process of a screener should include an evaluation of the following technical and usability characteristics.

Population of interest. Evaluating the norming sample for a selected screener is critical to understanding for whom the scores generalize and are best suited for implementation. An understanding of the intended age-range or grade-level of the child and operationalized definition of how risk is defined are both necessary for comparing

Evaluating the norming sample for a selected screener is critical to understanding for whom the scores generalize and are best suited for implementation.

and evaluating usefulness to the local context (e.g. dyslexia as <20th percentile or <5th percentile on an end of year, standardized word reading measure).

Scope of the assessment. Most screeners measure skills through speeded assessments designed to measure fluency (i.e. the automaticity of skills), accuracy assessments (e.g. computer-adaptive and computer-administered power based assessments) or observational assessments (e.g. teacher observations of child behaviours). Depending on the goal of the screening process and available resources for the assessment, certain types of assessments may be more feasible, such as where stable internet is not available or where computer adaptive assessments may not be tenable.

Reliability of scores.
The consistency of scores from a measure is necessary but insufficient statistical property to evaluate according to both the type of reliability that is reported in technical manuals

(e.g. internal consistency, test–retest, parallel form) as well as the technical adequacy of reported reliability.

Classification accuracy.
The correct identification of individuals who are at risk and not at risk for poor outcomes is often the hallmark of statistical adequacy in evaluating the quality of screener. Such statistics include the sensitivity of scores (i.e. the ability of the screener to correctly identify those who will not meet an expected threshold of performance on a later assessment), the specificity (i.e. the ability of the screener to correctly identify those who will meet or exceed an expected threshold of performance on a later assessment), the false positive and false negative rates and other important features of technical adequacy (e.g. predictive power, area under the curve and base rates).

Barriers, access, equity for screeners.
When used within a responsive, prevention framework, screening has tremendous potential to

> ... implementing a screener in a local context should be done by taking stock of not just the technical adequacy of the screener, but also administrative and ecological considerations for the learner...

reduce educational disparities. Armed with valid and reliable scores about how students are performing, school personnel are well positioned to provide effective instruction and interventions to all learners. However, there are several assumptions that must be met to ensure that screeners and the information gained from them do lead to improved academic performance. Unfortunately, for many learners, these assumptions are often not met.

For example, when students are receiving evidence based instruction, screeners can help teachers determine which students are not responding to classroom instruction or specific interventions and require more intensive support. However, students from vulnerable or discriminated populations (e.g. in the USA, students of colour, students attending high-poverty schools with many children who are growing up in poverty, students who are English learners and students with disabilities) are less likely to be receiving evidence-based instruction in the classroom or even in small

group instruction (**Morgan et al., 2015)**. Another assumption is that teachers, clinicians and other professionals who make use of screeners have the knowledge, expertise, experiences and cultural competence necessary to assess and interpret performance for these student populations. The differential diagnosis and treatment of language and learning differences and disabilities in these student populations is challenging for a number of reasons, including a lack of valid and reliable assessment tools, appropriate approaches to modifications of assessments and availability of alternative assessment approaches.

Unfortunately, conditions like these not only limit the potential of the screening process, but also contribute to the misrepresentation of vulnerable student populations in special education. Therefore, implementing a screener in a local context should be done by taking stock of not just the technical adequacy of the screener, but also administrative and ecological considerations for the learner,

> **... it is important that teachers, clinicians, and other practitioners engaged in the screening process develop their own cultural competence.**

the classroom context and the surrounding community. The administration format of the assessment may be a barrier in choosing a particular type of assessment based on whether the screener is given on an individual or group basis. As well, the choice of a screener should be informed by the administration and scoring time and the scoring format (i.e. manual scoring or automatic scoring). Choosing a screener should be informed by, for example, linguistic variability in the local setting compared to the norming sample of the screener, individual variations that arise from geographic settings where poverty and inequitable funding appropriations exist, parent/caregiver styles of communication, and alignment with styles of assessments. Moreover, data gathered from screeners should be interpreted in concert with other informal and formal assessment data, family and educational history, and other information available on the student and instructional context to help ensure that recommendations are representative of the student's

ability and free from bias. Finally, it is important that teachers, clinicians, and other practitioners engaged in the screening process develop their own cultural competence. Culturally competent educators are aware of their own culture, knowledgeable about cultural interactions around them and use that knowledge and awareness to support the needs of their diverse learners **(NEA, 2008)**. Cultural competence is particularly important in education settings, not only because many teachers do not share the cultural backgrounds of their students but also because many teachers report low levels of competence in working with students from different race, ethnic and cultural backgrounds and from low-income households **(Bogdan et al., 2019)**. Armed with greater cultural competence, practitioners can ensure that their interpretation of student performance on screeners and the instructional recommendations that follow are culturally and linguistically appropriate for the student's developmental level and needs.

The proper assessment of learning disabilities should consist of tests of various aspects of academic achievement. Wherever possible, these assessments should be standardized. However, assessments are not available in many languages. Assessments are also important for collecting data and on the prevalence and learning progress of children with disabilities **(Nel and Grosser, 2016)**. For example, South Africa does not yet have a standard tool for measuring the prevalence of learning disabilities nationally and therefore cannot know whether children with disabilities are receiving the educational supports they need **(Nel and Grosser, 2016)**. It should be a goal to construct these assessments based on the language and culture in different regions. Moreover, dynamic assessment, which is testing adapted based on a student's level of performance, can be particularly useful for assessing the learning trajectories and potential of children with learning disabilities **(see WG3-ch3 for a detailed description)**.

6.3 **.3**

PREVENTIVE EDUCATION MODEL

Currently most schools apply a 'wait to fail' or 'reactive approach' when it comes to learning disabilities. This is often referred to as the 'dyslexia paradox' in the domain of reading acquisition **(Ozernov-Palchik et al., 2016)**. However, several models and a range of legislation have tried to initiate a shift from a reactive to a proactive or preventative model, for example Individuals with Disabilities Education Act **(IDEA, 2004)**. In such a model, children are identified as being at risk for a learning disability using screening approaches followed by remediation/intervention within primarily general but also special education for children at risk with the aim to prevent a learning disability before it manifests.

These preventive or proactive approaches have already been

Currently most schools apply a 'wait to fail' or 'reactive approach' when it comes to learning disabilities.

> **... preventive or proactive approaches have already been shown to be successful for the prevention of reading disabilities.**

shown to be successful for the prevention of reading disabilities. For instance, it has been shown that word reading interventions are more effective for improving reading outcomes when administered in kindergarten and first grade than when they were administered during later elementary grades **(Wanzek and Vaughn, 2011)**. Overall, converging research strongly supports an early and targeted approach for the prevention of learning disabilities **(Catts et al., 2015; Catts and Hogan, 2020)**. In the USA, for example, numerous states have already passed legislation directly related to the prevention of SLDs. While these legislative efforts are primarily directed towards the prevention of dyslexia and language based learning disabilities, the concept of 'preventive education' is much older. For instance, within IDEA **(2004)**, the Response to Intervention (RtI) model is the primary approach for students at risk for SLDs and consists of assessment, instruction and intervention phases in three tiers **(for an overview see Grigorenko** **et al., 2020)**. The RtI model of SLD identification involves universal screening of all young students for early predictors of academic achievement. Based on the screening results, students who are 'at risk' for learning disabilities then receive tiered targeted intervention and their progress is monitored. Students who continue to perform below grade expectations despite intervention can be identified as having an SLD. While in theory, RtI offers a practical approach to early identification and intervention of students at risk for SLD, there are still some concerns and controversies with the approach **(Grigorenko et al., 2020)**. For example, many schools face challenges to implementing RtI adequately **(Balu et al., 2015; Fuchs and Fuchs, 2017)**. Thus, if interventions are not implemented properly, a student can mistakenly be identified as having an SLD, when their learning difficulty is actually due to poor instruction and remediation.

6.4

How can we support children who need extra help with their learning?

INSTRUCTIONAL DESIGN AND INTERVENTIONS FOR LEARNING DIFFICULTIES

In classrooms across the world, there are students with learning disabilities who demonstrate a lack of adequate progress relative to their peers. How does a teacher effectively embrace a large range of learners and maximize opportunities for success for all? There are far more students who struggle with learning than have been diagnosed with a specific disorder. Unfortunately, this field still lacks large-scale evidence based studies systematically testing the effectiveness of various interventions for children with learning difficulties. As stated by Vaughn and Fletcher **(2020)**, we know more about the science of reading than the science of reading instruction. Classroom teachers and instructional support staff

> As stated by Vaughn and Fletcher, we know more about the science of reading than the science of reading instruction.

can take small but intentional steps daily to ensure access to the curriculum for all of their students. The techniques and methods shared in this section will provide quick, time efficient and evidence based practices associated with improved outcomes for children with learning disabilities but also improved learning outcomes for students who do not have learning difficulties **(Vaughn et al., 2000)**. Although these practices can benefit an entire class, they can be essential for children with learning disabilities. We will provide examples of how to accommodate and support children with learning disabilities while also providing opportunities for skill building through the following instructional approaches: (1) design; (2) key daily practices; (3) classroom interventions; and (4) one-minute interventions.

6.4	.1	.1

INSTRUCTIONAL DESIGN

Explicit instruction is an effective research based feature of instructional design. Explicit instruction can be used across all grades and classrooms, as it is not specific to any single curriculum or intervention but is 'systematic, direct, engaging and success-oriented' **(Archer and Hughes, 2010)**. Four ways to integrate explicit instruction into any lesson and/or unit to increase opportunities for successful learning **(Vaughn and Fletcher, 2020) are**: (1) break down or chunk complex tasks into more manageable units; (2) purposefully introduce manageable chunks and connect them to previous learning, so that students can build skills to accomplish an advanced task; (3) provide brief and precise instructions using modelling or think-aloud in daily practice to address the important features of the content (e.g. show students in an organized and clear manner how to do something); and (d) utilize routines that move fluidly from modelling to guided practice and ultimately independent practice when teaching new tasks.

6

... instruction should: be explicit and systematic; foster high levels of engagement, on-task behaviour, and emotional support ...

6.4	.1	.2

KEY DAILY PRACTICES

Examples of instructional practices that can be integrated into every lesson to support atypical learners include multiple opportunities for students to respond and heterogeneous grouping to facilitate cooperative learning, purposeful practice and feedback. Daily opportunities to respond mean that during every lesson, students respond to prompts either through engaging in discussion, writing or using response tools (e.g. dry erase boards). Students can respond with a partner, small group or the whole class. Heterogeneous grouping refers to students with different skills and abilities working together to learn from their peers, as students with stronger skills can provide a model for less proficient students **(Baker et al., 2014)**. Perhaps most importantly, frequent opportunities for practice can provide purposeful time for students to utilize all new skills and refresh learned ones **(Swanson and Deshler, 2003; Vaughn and Fletcher,**

2020). Lastly, purposeful feedback, especially when provided immediately, can help guide students through error correction.

6.4	.1	.3

CLASSROOM INSTRUCTION

To support all children in the classroom, particularly those with maths difficulties, instruction should: be explicit and systematic; foster high levels of engagement, on-task behaviour, and emotional support **(Namkung et al., 2019)** using motivational techniques and positive reinforcement; provide multiple opportunities to respond and receive immediate feedback; and use frequent retrieval practice and cumulative review **(Fletcher et al., 2019)**. Whole-class techniques include peer tutoring in which lower and higher performing children are purposefully paired to work on discrete maths skills, taking turns being the teacher and the learner. To effectively introduce new maths skills, teachers break down a problem into its underlying conceptual

structure, use concise language as they model the steps to solve the problem, and then encourage student verbalization of the steps. It is also helpful to draw connections between mathematical concepts and authentic, real-world representations.

Mathematical difficulties can greatly impact both individuals and societies **(National Mathematics Advisory Panel, 2008)**. Because maths difficulties are relatively stable from kindergarten to the end of high school **(Shalev et al., 1998, 2005; Morgan et al., 2011)**, high-quality classroom instruction is important for all, with intensifying intervention needed for children who do not respond adequately to instruction. There are several domains of mathematics (think whole number operations to trigonometry) and fluency in one domain may be foundational for, but not sufficient to, transfer to success in another **(Fuchs et al., 2009)**. This necessitates ongoing, universal maths screening and assessment; children whose previous maths difficulties have been remediated may require

additional intervention as the curriculum changes, and children without previous difficulties may begin to struggle when new domains are introduced.

6.4	.1	.4

THE POWER OF ONE-MINUTE INTERVENTIONS

While it may not be possible for a teacher to provide thirty minutes (or more) of intensive support to students who need additional instruction, the power of a one-minute intervention should not be underestimated as it can be incredibly useful to reteach, practise, make learning more explicit and give feedback to selected student(s). Two powerful one-minute interventions are: One-Minute Check-In and One-Minute Feedback. One-minute interventions can happen at any time while the majority of students are engaged in work (i.e. turn and talks, group work, individual work). A One-Minute Check-In is when a teacher circulates to check-in with

While it may not be possible for a teacher to provide thirty minutes (or more) of intensive support to students who need additional instruction, the power of a one-minute intervention should not be underestimated as it can be incredibly useful to reteach, practise, make learning more explicit and give feedback to selected student(s).

Effective teacher feedback is a feature consistently associated with improved student outcomes.

individual students reviewing and practising target skills. This would also be a great time to gather information from students' responses to determine what to reteach or review. One-Minute Feedback is when a teacher meets with one to two students to explain why their responses are correct or incorrect or help students develop stronger responses. Teacher feedback should be clear, focused and directly related to the learning task and guides the student(s) to continue and/or to adjust learning practices. Effective teacher feedback is a feature consistently associated with improved student outcomes **(Hattie, 2009)**.

It should be noted that a small percentage of students with persistent learning difficulties may not adequately respond, even to high-quality instruction and intervention **(Fuchs et al., 2008; NCII, 2013)** and might need individualized instruction **(NCII, 2013)**, when possible. For these students, we encourage educators to consider how they might intensify the practices we

recommend here. For example, it may be important to remember that students with the most intensive needs may require ten to thirty times as much practice as their peers **(Gersten et al., 2009)** and may profit from tutoring. With attention to instructional design, key daily practices and one-minute interventions, teachers can more effectively embrace a large range of learners and provide opportunities for success for all.

| **6.4** | .1 | .5 |

SMALL GROUP INTERVENTIONS

Effective whole group practices are necessary, but not sufficient, for children with significant maths difficulties. Take for example maths word problem-solving with whole numbers **(Fuchs et al., 2009)** or fractions **(Fuchs et al., 2017)**. Students with maths difficulties will need additional ongoing written and graphic support for the steps that have been modelled **(Jitendra, 2002)**, as well as guided practice in verbalizing the steps. Instruction in higher-level skills,

such as maths problem-solving, is essential even if foundational skills require continued support; for example, five-minute calculation practice in thirty-minute word problem-solving lessons improved both calculation and problem-solving **(Fuchs et al., 2009).** Teaching practices that maximize solution predictability and minimize constraints on memory and reasoning are helpful for learning and transfer. For example, the three most common word problem types in early elementary school are combine, compare and change problems, which can be taught in categories so that not every problem seems novel **(Fletcher et al., 2019).** Also important for transfer is contextual variation in which students solve standard and non-standard problems with similar underlying conceptual structures to improve more abstract mathematical reasoning, such as relational understanding of the equal sign (e.g. $4 + x = 7$ versus $7 = x + 4$) **(Powell et al., 2020).** For children who do not respond to the combination of high-quality classroom based maths instruction

and small group interventions described here, techniques for further intensification are in Powell and Fuchs **(2015)** and Powell and Stecker **(2014).** Research specific to interventions for secondary school students are in Jitendra et al. **(2018).**

| 6.4 | .1 | .6 |

HIGH DOSAGE TUTORING: A PROMISING INTERVENTION FOR PUPILS STRUGGLING WITH MATHS

Researchers and policy-makers alike have for decades lamented how rarely interventions aimed at disadvantaged (middle and high school) students successfully generate measurable increases in student performance as measured by standardized achievement tests. This fact, along with the strong results emerging from meta-studies based on randomized controlled trials (RCTs) or quasi-experimental designs investigating the effectiveness of various kinds of tutoring interventions **(Gersten et al., 2009; Ritter et al., 2009; Dietrichson et al., 2017; Nickow, Oreopoulos and**

> Teaching practices that maximize solution predictability and minimize constraints on memory and reasoning are helpful for learning and transfer.

High dosage tutoring is an intensive form of tutoring used at present mainly to help middle and high school students struggling with mathematics.

Quan, 2020; Pellegrini et al., 2021), help explain the recent excitement about the possibility that tutoring programmes can offer as an effective means of addressing persistent (if not growing) inequalities in educational outcomes among more and less privileged learners (Ander, Guryan and Ludwig, 2016; Kraft and Falken, 2020; Slavin et al., 2020). This state of affairs highlights the following question: which specific types of tutoring interventions appear to be most effective with regard to consistently driving measurable increases in academic skills and outcomes?

High dosage tutoring (HDT) is an intensive form of tutoring used at present mainly to help middle and high school students struggling with mathematics. In several settings in the USA and, more recently, the Netherlands (where the findings are still preliminary), smaller and larger scale RCTs have repeatedly demonstrated that this form of tutoring can generate breakthrough outcomes for disadvantaged pupils for whom typical classroom educational

experiences have (at least in the domain of mathematics) not been effective (Cook et al., 2014, 2015). Increasingly cost-effective HDT models are being tested by various teams of independent evaluators in the US and in the Netherlands (Cook et al., 2014, 2015; Fryer, 2014; Kraft, 2015; Fryer and Howard-Noveck, 2020). At each stage, RCTs are pinpointing the standard deviation treatment effects that correspond, at least in the settings in which they have been tested, to the various models. The aim is to produce, for policy-makers and professionals, customized models that are both RCT tested and inexpensive enough that they can be offered at a large scale to disadvantaged students.

HDT is characterized by highly personalized instruction in a small group tutorial setting. Paraprofessional tutors who are usually not certified teachers (e.g. graduates of BA programmes offering a 'service year' before moving on to graduate studies) offer tutoring sessions during regular school hours primarily to students who have fallen

(many years) behind grade level in maths. A number of non-profit organizations offer this more or less clearly identifiable type of tutoring, including Saga Education in the USA **(sagaeducation.org)** and The Bridge Learning Interventions in the Netherlands **(tbli.nl)**. In the versions of HDT offered by these organizations, a 'site director' helps tutors individualize lesson plans before tutoring sessions, monitors what goes on in the tutoring room during these sessions and offers ongoing feedback to each tutor thoughtout what is typically a year long intervention. Tutors maintain regular contact with their students' parents or guardians (e.g. through weekly or bi-weekly phone calls). A central aim is to bring students back up to grade level so that they can re-engage with regular classroom material. Crucially, tutors attempt to find what precisely each learner is struggling with in a given domain (e.g. subtraction or decimals) and what the best strategies are for helping them gain confidence by overcoming the specific barriers they face. Unlike classroom teachers, tutors have the luxury of helping their pupils with specific areas of learning until they genuinely achieve and demonstrate mastery. For obvious reasons, this has implications for both the development of skills usually associated with social emotional learning (SEL) and the plausibility of longer-term treatment effects. The latter, however, remains uncertain and requires more (RCT based) evaluations drawing on longitudinal data.

A central challenge, in the years ahead, will be to create and sustain the conditions in which consistent execution of HDT can be achieved. Training, careful monitoring, adaptations to specific contexts and, where necessary, 'fidelity recovery' will be essential as HDT interventions are scaled up and rolled out in new settings. This will require deep and durable partnerships between managers of non-profit organizations offering HDT, on the one hand, and, on the other, consortium members representing public schools, public school districts/managerial authorities, (local)

> Training, careful monitoring, adaptations to specific contexts and, where necessary, 'fidelity recovery' will be essential as HDT interventions are scaled up and rolled out in new settings.

governments and philanthropic organizations. The 'joining up' or 'co-creation' approach most famously developed by the Abdul Latif Jameel Poverty Action Lab, or J-PAL, appears to offer the most actionable insights into how such bridging of scientific research and educational reform – including HDT – can be achieved moving forward.[6]

6.4   .1   .7

NEW RESEARCH

Given that cognitive competencies such as attention, working memory and spatial cognition are related to mathematics **(Bailey, Dunlosky and Hertzog, 2014; Verdine et al., 2014; Peng et al., 2016)**, can we improve maths with cognitive training? Cognitive competencies do appear to determine for whom a particular intervention is more or less effective **(Fuchs et al., 2013; Swanson, 2014)**. Understanding how and why the cognitive abilities children bring into the instructional setting with them interact with particular

instructional components will be valuable for improving the fit between our interventions and the children they are meant to help. Given that maths and reading difficulties often co-occur, even early on **(Willcutt et al., 2013; Barnes et al., 2020)**, research to design feasible and efficient interventions that concurrently address difficulties across academic domains (e.g. reading comprehension and maths word problems) is needed and underway. In sum, current evidence supports the use of maths-specific whole class and small group interventions such as those described above while also considering the cognitive **(WG3-ch3)** and emotional competencies **(WG3-ch4)** that children bring into the learning context.

We are confident that with attention to instructional design, key daily practices and one-minute interventions, teachers can more effectively embrace a large range of learners and provide opportunities for success for all.

[6]https://www.povertyactionlab.org/case-study/individualized-tutoring-improve-learning

6.4 .2

ASSISTIVE TECHNOLOGY

Disabilities manifest themselves in many different forms and severities. Yet, the single unifying characteristic of students with disabilities involves challenges and difficulties in performing routine tasks at a level comparable to their peers. Assistive technology (AT) is sometimes considered an equalizer **(Michaels and McDermott, 2003)** because of its potential to enhance academic, behavioural, social and economic outcomes of students with disabilities. The right AT augments, bypasses or compensates for a disability.

The WHO **(2018)** describes AT as follows.

- AT is an umbrella term covering the systems and services related to the delivery of assistive products

and services.

- Assistive products maintain or improve an individual's functioning and independence, thereby promoting their well-being.

- AT enables people to live healthy, productive, independent and dignified lives, and to participate in education, the labour market and civic life. AT reduces the need for formal health and support services, long-term care and the work of caregivers. Without AT, people are often excluded, isolated and locked into poverty, thereby increasing the impact of disease and disability on a person, their family and society.

- The United Nations Convention on the Rights of Persons with Disabilities **(2006)** has afforded AT the status of a human right. For this reason, ratifying countries commit to facilitating access to AT solutions for those who need them in order to foster participation in

... the single unifying characteristic of students with disabilities involves challenges and difficulties in performing routine tasks at a level comparable to their peers.

When appropriate AT devices and services are provided, an individual is able to complete tasks more effectively, efficiently and independently than otherwise possible without the tools.

democratic society on an equal basis with others and improve independence in daily life.

The value and significance of AT can be understood in relation to performance problems. That is, a person with a disability encounters a task they are unable to successfully complete. Following the identification of an appropriate AT device, acquisition of the product, as well as training and support in its use, a person is subsequently able to use their AT to complete the same task that was previously difficult or impossible. When appropriate AT devices and services are provided, an individual is able to complete tasks more effectively, efficiently and independently than otherwise possible without the tools **(WG2-ch6)**. See **Box 5** for examples of how AT can support individuals with autism.

Despite the general advocacy for AT by policy-makers, educators and developers, there is no credible evidence to suggest that everyone who could benefit from AT has access to appropriate AT devices

and services **(Edyburn, 2020)**. As a result, AT is an under-utilized intervention to provide pupils and students with special needs and disabilities, a means for accessing and engaging in the curriculum in ways that are representative of the ubiquitous nature of technology in society. As a first course of action, we should be mindful that advances in universal usability have provided accessibility tools on every smartphone, computer tablet, laptop and desktop computer. Parents and educators are encouraged to explore the accessibility features on their devices as a critical first step in locating appropriate AT to help a struggling student.

At this time, only a small number of AT interventions can be documented as having a moderate or strong evidence base **(Anttila et al., 2012; Brandt, Hansen and Christensen, 2020)**. There is a considerable need for AT research that focuses on quantitative measures of return on investment and performance under varying conditions. Studies by Koester and Arthanat **(2018a, 2018b)**

offer a model for AT research that advances the profession's empirical evidence base while simultaneously providing critical data for consumer decision-making about what works rather than simply relying on consumer satisfaction. For more detailed

There is a considerable need for AT research that focuses on quantitative measures of return on investment and performance under varying conditions.

BOX 5. ASSISTIVE TECHNOLOGY AND AUTISM

Approximately 25 per cent of autistic children are non-speaking/minimally verbal. Often, people assume that these children do not understand speech or are incapable of communicating. However, speech is not a proxy for intelligence, and using non-invasive technology such as electroencephalogram (EEG) it is possible to identify good receptive language skills in non-speaking autistic individuals **(Petit et al., 2020)**. Once these children are identified, it is then possible to augment communication with augmentative and alternative communication (AAC) technology. This technology ranges from simple cardboard letterboards to eye-tracking and EEG devices. While using AAC can be quite effective, it must be individualized and can require a lot of trial and error as well as intensive training for both user and any communication supporters that are required. Additionally, while speech averages to 150 words/min, AAC at best achieves 10 word/min **(Chang and Anumanchipalli, 2020)**, thus there is much room for improvement. Further considerations must also be made when thinking globally. While cardboard letterboards are easily scalable, EEG and eye-tracking technology may be more difficult to implement depending on regional resources **(see WG2-ch6** social robots and autism**)**.

[7] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/926052/specific-learning-difficulties-spld-cst-report.pdf

6.5 Teacher and parent education and advocacy

6.5 .1

FAMILY SCHOOL PARTNERSHIP IN EDUCATION

Across the literature, many different terms are used to depict the interaction of families with the school system. For example, authors describe 'family involvement', 'family engagement', 'parent engagement', 'family interaction', 'parent–school relationships' and 'family partnership'. In this section, we apply the term 'family–school partnerships'. Turnbull et al.

> **Positive, trusting partnerships are crucial for educational systems to function effectively and enable all stakeholders to benefit.**

(2021, p. 8) state that family–school partnerships are 'characterized by an alliance in which families and professionals confidently build on each other's word, judgment, and wise actions to increase educational benefits to students and themselves'. They conceptualize family–school partnerships as relationships that encompass and surpass parent/family involvement and engagement. Whereas 'involvement' refers to families merely taking part in an activity, partnership embodies equity, mutual responsibility and commitment **(Christenson and Reschly, 2010; Hornby, 2011; Goodall and Montgomery, 2014; Epstein et al., 2018)**. Parental involvement is a prerequisite to family–school partnership **(Hornby and Blackwell, 2018)**. Positive, trusting partnerships are crucial for educational systems to function effectively and enable all stakeholders (e.g. children, parents, teachers, school administrators) to benefit **(Francis et al., 2016a, 2016b; Haines et al., 2017)**.

6.5 .1 .1

OUTCOME AND IMPACTS OF PARTNERSHIP

Family–school partnerships are important in the education of all children, both with and without disabilities **(Fox, 2005; Goldman and Burke, 2017; Kyzar et al., 2019; Mantey, 2020)** and lead to positive learning outcomes, academic achievements and improved self-esteem of the child **(Henderson and Mapp, 2002; Fox, 2005; Rogers et al., 2009; Mantey, 2020)**. For example, Kurni et al. **(2009)** highlight that deeper partnerships between parents and the school lead to greater improvement in the emotional, social, behavioural, language, cognitive and motor skill development of children with a learning disability. Partnerships are critical to the successful implementation of an inclusive education programme at all school levels **(Fox, 2005; Kurani et al., 2009; Goldman and Burke, 2017)**. This is because parents and families more generally have an advanced understanding of their child's capacity, needs,

Families from diverse cultural backgrounds can, and often do, have a positive influence on their children's learning

abilities, limitations, likes/dislikes and ways of coping with challenging situations, and can provide meaningful insights for their child's learning and growth **(Henderson and Mapp, 2002; Kurani et al., 2009; Rogers et al., 2009; Kyzar et al., 2019)**. If families are engaged in the education of their children with a disability, their stress levels are reduced, and their sense of fulfilment, satisfaction and self-confidence is simultaneously increased **(Reio Jr and Fornes, 2011; Fishman and Nickerson, 2015; Park and Holloway, 2017)**. It can also lead to improved parent–teacher relationships, improved teacher morale and school climate **(Hornby and Blackwell, 2018)**. Partnering with families in education enables various stakeholders to be aware of the child's disability **(Fox, 2005; Mantey, 2020)**, can reduce stigma around the child's disability **(Kurani et al., 2009)** and empowers families to be advocates and active change agents **(Rogers et al., 2009; Singal, 2016)**. Several authors highlight that partnerships between families and teachers provide a safe and sound foundation for the children to explore their

social environment, and can result in improved academic outcomes (i.e. grades, attendance), increased cooperative behaviour and lower dropout rates **(Kurani et al., 2009; Goldman and Burke, 2017; Tuggar, 2019; Mantey, 2020)**. This relationship holds across families of all economic, racial/ethnic and educational backgrounds and for students of all ages and abilities **(Marcon, 1999; Henderson and Mapp, 2002; Reynolds and Shlafer, 2010)**. Families from diverse cultural backgrounds can, and often do, have a positive influence on their children's learning (e.g. some are more involved at home, others more at school and some at both) **(Lareau and Horvat, 1999; Jordan, Snow and Porche, 2000; Fan and Chen, 2001; Reynolds and Shlafer, 2010)**. For example, Sui-Chau and William**s (1996)** highlight that in an American context, Asian, Hispanic, African American and white parents were equally active in their middle and high school children's education.

> cultural and power imbalances between families and teachers due to education differences and stigma around the child's disability may lead families to believe that teachers know more about children's education and, thus, affect their partnerships with teachers.

6.5 | **.1** | **.2**

BARRIERS TO PARTNERSHIPS

Hornby and Blackwell **(2018)** identify four types of barriers to the establishment of effective family–school partnerships.

1. Parent and family barriers: parents' belief about their engagements, family's current life context, SES – limited financial capacity, time and energy, ethnicity and gender **(Hornby and Lafaele, 2011; Hornby, 2015; Hornby and Blackwell, 2018)**

2. Child factors as barriers: children's age, type of special need, grade level **(Fishman and Nickerson, 2015)**, learning difficulties, disabilities and behavioural problems **(Hornby and Lafaele, 2011)**

3. Family–teacher factors as barriers: differing agendas, attitudes and language **(Hornby and Lafaele, 2011)**, as well as communication difficulties for families of children with disabilities with lower education

levels **(Hornby and Blackwell, 2018)** (e.g. difficulties in understanding school based materials **(Hornby and Blackwell, 2018)**, limited understanding about their child's disability and disability-related needs **(Šukys et al., 2015)** can negatively affect partnerships. Additionally, cultural and power imbalances between families and teachers due to education differences and stigma around the child's disability may lead families to believe that teachers know more about children's education and, thus, affect their partnerships with teachers **(Reio Jr and Fornes, 2011; Fishman and Nickerson, 2015; Šukys et al., 2015)**. Other barriers include teachers' lack of time, minimal direct and targeted communication, lack of training or limited invitations for family involvement and little individualized attention to partnering with families **(Fishman and Nickerson, 2015; Hornby and Blackwell, 2018)**.

4. Societal barriers: historical, demographic, political, religious and economic issues **(Hornby and Lafaele, 2011)**, prevailing stigma

around the child's disability **(Singal, 2016)** and racism experienced by the child in the classroom **(Hornby and Blackwell, 2018)**.

To improve family, teacher and child outcomes, schools should strive to reduce or eliminate barriers that prevent positive and effective family–school partnerships.

6.5	.1	.3

WHAT NEEDS TO BE DONE?

Several authors highlight the need to create school environments that are supportive and accepting, and that promote inclusion and equity, including understanding and consideration of diverse cultures **(Francis et al., 2016b; Goldman and Burke, 2017; Park and Holloway, 2017; Gonen-Avital, 2018; Rivera-Singletary and Cranston-Gingras, 2020)**. School leadership is key to fostering values and behaviours that can create a positive school culture where parents feel safe and encouraged to collaborate **(Lendrum, Barlow and Humphrey, 2015; Francis et al., 2016b;**

Hirano and Rowe, 2016; Goldman and Burke, 2017)**. Such partnerships require mutual communication, respect, equality, trust and commitment from families and schools **(Francis et al., 2016a, 2016b; Al-Dababneh, 2018)**. Globally, many parents lack the knowledge and confidence to be active partners in their child's education, hence strengths based, culturally relevant training/workshops for parents can enhance awareness of their own and their child's rights, develop their skills and motivate proactive involvement **(Al-Dababneh, 2018; Mantey, 2020; Rivera-Singletary and Cranston-Gingras, 2020)**. Families need opportunities for leadership development so that they can partner in their child's day-to-day education, but also collaborate in policy development for implementing effective inclusive education **(Francis et al., 2016a; Shepherd and Kervick, 2016; Tuggar, 2019; Rossetti et al., 2020)**. Establishing parent or family networks and support groups can also enhance positive family–school partnerships as families feel a sense of support and belonging within the school community **(Fishman and Nickerson,**

> ... create school environments that are supportive and accepting, and that promote inclusion and equity, including understanding and consideration of diverse cultures.

> **Families need opportunities for leadership development so that they can partner in their child's day-to-day education, but also collaborate in policy development for implementing effective inclusive education.**

2015; Park and Holloway, 2017; Al-Dababneh, 2018; Rice, 2018; Jigyel et al., 2019). In particular, more support is needed for families of lower socio-economic backgrounds and for involving fathers **(Goldman and Burke, 2017; Park and Holloway, 2017; Jigyel et al., 2019)**. Additionally, teachers require support and training (initially and ongoing) so that they can competently address the educational needs of all children and effectively partner with families **(Fishman and Nickerson, 2015; Kayama et al., 2017; Rice, 2018; Kyzar et al., 2019; Mueller, 2019)**.

6.5 .2

EMPOWERING TEACHERS WITH THE SCIENCE OF LEARNING

Understanding how the brain develops and the role of experience can transform how teachers view students' learning potential **(Ansari et al., 2017)**. Therefore, an understanding of the science of learning can empower teachers with the knowledge to customize or adapt instruction to better target student learning needs. Such knowledge would be especially empowering for teachers of students with learning disabilities. Moreover, basic reading and maths skills are powerfully linked to a country's economic growth, individual earnings and the distribution of the country's incomes **(Hanushek and Woessmann, 2008)**. In the USA, the National Institute of Health considers illiteracy an issue of public health and has provided extensive funding support to identify reasons for the high incidence of reading problems and to develop appropriate evidence based practices to help children become better readers. According to the National Assessment of Educational Progress **(2019)**, 33 per cent of students in grade 4 in the USA cannot decode and comprehend grade 4 reading materials, with this percentage reaching as high as 66 per cent among minority and inner-city school children. Moreover, in

the USA, Juel **(1988)** finds that children who read poorly at the end of grade 1 are likely to remain poor readers at the end of grade 4. Similarly, Landerl and Wimmer **(2008)** find that in Germany about 70 per cent of poor readers in grade 1 are also poor readers in grade 8. Although various factors, such as low socio-economic status **(Fahle and Reardon, 2018)** and home literacy environment **(Chiu and McBride-Chang, 2006)**, may contribute to the high incidence of reading problems, Denton, Foorman and Mathes **(2003)** assert that effective instruction can 'beat the odds'. Thus, it is imperative to provide a strong instructional foundation at early grade levels to prevent future reading problems. However, the question arises: are teachers prepared to provide explicit, systematic instruction?

6.5 **.2** **.1**

WHAT TEACHERS NEED TO KNOW

The reality of educating students in a group context is that they are all learners with differences. The learning sciences demonstrate that a learner's ability is not fixed. That being the case, state-of-the-art teacher training, in addition to focusing on training about individual differences in learning, can now also provide more concise information about how to use formative assessment to identify and teach to students' strengths. Formative assessment is important for leading students from where their skills are now and what they know to what comes next. A student could compensate for a learning difficulty with their strengths in other areas. For example, gifted students may underachieve because they also have a learning disability, such as dyslexia, that may go unnoticed because they manage to perform at an average level **(Kalbfleisch, 2013)**. Unless a teacher can understand the context of the behaviour, they will have little success at influencing the students' learning. More precise and elaborate training about learning and individual differences prepares a teacher by improving their ability to adapt the content, process and flow of instruction to benefit students.

... it is imperative to provide a strong instructional foundation at early grade levels to prevent future reading problems.

> **Formative assessment is important for leading students from where their skills are now and what they know to what comes next.**

Studies have consistently shown that teachers lack explicit knowledge of constructs related to language and literacy **(Moats, 1994)**, particularly in concepts such as phonemic awareness, phoneme and morpheme identification, etymology of words, and word origins **(Cunningham et al., 2004; Brady et al., 2009)**. Additionally, teachers exhibited poor understanding of dyslexia **(Washburn et al., 2017)** with many teachers believing dyslexia was reversals of letters and words. This lack of knowledge among teachers was observed in other English-speaking countries (i.e. UK, Canada, New Zealand) in addition to the USA **(Washburn et al., 2016)**. For instance, in-service teachers from all four countries performed poorly on tasks relating to morphological awareness. However, there were differences among countries as teachers from the UK performed better on items relating to phonics while teachers from the USA performed better on items relating to phonological awareness. Similar findings have been observed among teachers of English as a foreign language (EFL). For instance,

both Chinese and Korean EFL teachers demonstrated weaknesses in their explicit knowledge of phonological awareness, phonemic awareness and phonics **(Zhao et al., 2016; Bae, Yin and Joshi, 2019)**. Among EFL teachers in Israel, Vaisman and Kahn-Horwitz **(2020)** find that teachers who perform poorly on phonological awareness tasks spend less time teaching those concepts than teachers who perform better on these tasks.

It has been shown that when in-service teachers are trained in explicit evidence based instruction, students' reading performance improves significantly **(McCutchen et al., 2009; Piasta et al., 2009; Ehri and Flugman, 2018)**. This trend is reflected in low- and middle-income countries as well, where providing teacher guides and teacher training are significant predictors of improved reading outcomes **(Piper et al., 2018)**. Binks-Cantrell et al. **(2012)** observe that pre-service teachers taught by university professors with explicit knowledge of literacy concepts perform better on such tasks compared to pre-service

6

CHAPTER

Empowering teachers with the science of learning means a rethink of the profession of teaching.

teachers taught by university professors lacking such knowledge. This may affect the reading performance of students taught by teachers without sound knowledge of the concepts.

As noted above, poor reading skills may have debilitating effects on the individual, society and nation, but students, especially at early grade levels, can be helped by providing explicit, systematic instruction. However, both pre- and in-service teachers, along with the university professors who train these teachers, lack knowledge about concepts relating to explicit instruction. Thus, colleges of education must do a better job of training teachers and ensuring their instructors possess the knowledge to do this effectively.

6.5   .2   .2

DIRECTIONS FOR FUTURE RESEARCH AND POLICY ACTION

Empowering teachers with the science of learning means a rethink of the profession of teaching. We need to empower teachers

with not only science of learning and pedagogical competencies but also scientific knowledge on domains such as neuroscience and cognitive science in order to prepare them to deal with students with learning difficulties. Teachers are not traditionally trained to be clinical practitioners, where evidence and judgement are used to identify learning difficulties. Developing targeted remediation plans to support learners to reach their full potential in light of their assessed learning abilities requires specialized training **(Guerriero, 2017)**. Teachers participating in the 2018 edition of the Teaching and Learning International Survey (TALIS) teacher survey self-reported that they continue to need professional development on student assessment, analysis and use of student assessment data, and teaching students with learning disabilities **(OECD, 2019)**.

6.6 [Special and inclusive education](#)

One of the most critical issues in education involves the optimal way to provide good educational services to students with disabilities. Educational services to children exist on a continuum from special education to inclusive education. Although special education and inclusive education are sometimes depicted as polar opposites, in reality there are many degrees of both. In the extreme version of special education, children are taught in special schools according to their disability. Additionally, these children are often congregated into segregated classrooms according to their disability. In contrast, inclusion is a human-rights based approach to education where there is respect for diversity and 'all members of the learning community are welcomed equally ... All students must feel valued, respected, included and listened to' **(UN, 2016, p. 5)**. Therefore, inclusion is important for equitable education.

6.6 **.1**

EFFECTIVENESS AND LIMITATIONS OF SPECIAL AND INCLUSIVE EDUCATION

6.6 **.1** **.1**

UNDERSTANDING SPECIAL EDUCATION AND INCLUSIVE EDUCATION

The special education versus inclusive education debate has ensued for more than quarter of a century. Inclusive education as a notion emerged from the special education field, when academics, educators and families challenged the segregation of students on the basis of disability, and it was formally declared as the prevailing philosophy for the education of students with a disability in the Salamanca Statement **(UNESCO, 1994)**. More recently the Convention on the Rights of

Persons with Disabilities **(UN, 2016)** and the Incheon Declaration and the Framework for Action **(UNESCO, 2016)** have sought to ensure that inclusive and equitable quality education for all remains on the agenda of governments globally. Yet inclusive education finds itself interminably entangled in the politics of disability and special education **(Artiles and Kozleski, 2016; Mac Ruairc, 2020)**, and to date there are few, if any, systems that are inclusive of all students **(Boyle and Anderson, 2020)**.

Special education provides schooling to students with disabilities (both physical and psychological in nature) in separate educational settings from that of their peers without disability. Education should be designed to provide the best education for all children. For example, if a child gets some specialized help outside the classroom (Braille, sign language, specialized help for dyslexia, etc.), but spends most of the time in a general classroom, is it considered inclusive or special education?

Critics of special education describe it as discriminatory and exclusionary, and situate inclusive education as a fairer more just way of doing education that benefits all students.

It is important to recognize that inclusive education does not mean that a student cannot get specialized help outside the classroom walls. Detractors of inclusive education position it as the enemy of special education **(Imray and Colley, 2017)**, and continue to advocate for separate educational provision for students with disabilities on the grounds that it better serves their needs **(Kauffman et al., 2020)**. Critics of special education describe it as discriminatory and exclusionary, and situate inclusive education as a fairer more just way of doing education that benefits all students **(Graham, 2020)**. It is perhaps unsurprising that the education of students with disabilities (and other learning needs) has been described as a wicked problem **(Armstrong, 2017)**, one for which there is no simple solution.

education exist within complex cultural and social contexts **(Duke et al., 2016)** and Arduin **(2015, p. 112)** notes that it is the 'understandings, beliefs and assumptions' of these contexts that will guide the way phenomena, such as special education and inclusive education, are understood. Consequently, interpretations of special education and inclusive education will differ from place to place and as contexts change over time **(Carrington, Tangen and Beutel, 2019)**, having an impact on discussions about everything from education policy, to curriculum and pedagogy, to school structures **(Cooc and Kiru, 2018)**. This is evident in the variation between special education and inclusive education policies, both within and between nations **(Hardy and Woodcock, 2015)**.

6.6	.1	.2

CHALLENGES OF SPECIAL EDUCATION AND INCLUSIVE EDUCATION

Special education and inclusive

6.6	.1	.3

ESSENTIAL FOR SOME, GOOD FOR ALL' – MULTI-TIER SYSTEMS OF SUPPORT (MTSS): UNIVERSAL DESIGN FOR LEARNING AND DIFFERENTIATED INSTRUCTION

> Research in ability grouping indicates that it is not successful for improving academic outcomes in lower ability students and in fact creates more inequity rather than alleviating it.

It is important to note that the central idea of inclusive education is that a student receives the best and most comprehensive education that is appropriate for their needs. The Multi-Tier Systems of Support (MTSS) framework sets up children for success rather than taking a 'wait and fail approach'. Tier 1 consists of universal strategies (i.e. Universal Design for Learning – UDL) that plan for a range of learners in the classroom from the beginning rather than attempting to change lessons once teachers are aware of the learners in their classroom. UDL principles and guidelines support curriculum and instruction that is maximally accessible through multiple means of: (a) representation by presenting information through different modalities; (b) expression by enabling students to express their knowledge through oral, written or other modalities; and (c) engagement by providing multiple ways to motivate and engage students **(CAST, 2018)**. Tiers 2 and 3 of the MTSS framework exist for students whose learning needs are not met at the universal

Tier 1 level. No one would deny that some students require tier 2 and 3 support, and that sometimes this help must occur outside the general classroom. Research in ability grouping indicates that it is not successful for improving academic outcomes in lower ability students **(Spina, 2019)** and in fact creates more inequity rather than alleviating it **(Parekh and Brown, 2019)** which is, in fact, harmful **(Oh-Young and Filler, 2015)**.

Within an inclusive framework, MTSS supports the development of individual learning profiles that provide a strengths based approach to help guide educators' support of the child. Learning profiles provide guidance for differentiating the instructional programme for a child. Differentiating requires structuring lessons in such a way that each student has an opportunity to work at a moderately challenging, developmentally appropriate level. Teachers can differentiate: (a) the content (what the students are learning); (b) the process (the activities); and (c) the products (the accomplishments that show learning) **(Tomlinson, 2017)**, but

In classrooms where teachers use universal design for learning and differentiated instruction, they accept that students differ in important ways.

Tomlinson would argue that groups must be flexible, dynamic and varied and that if done correctly, no student would ever be in Tier 2 and 3 all the time.

In classrooms where teachers use universal design for learning (UDL) and differentiated instruction (DI), they accept that students differ in important ways. Classroom teachers can engage in all three tiers within the classroom. At times, supports may be needed for successful learning and there may be times when students engage in learning outside of the classroom environment, but the goal must always be to learn with their peers in their neighbourhood school.

6.6 .2

CHALLENGES AND APPLICABILITY IN VARIOUS GEOGRAPHICAL/ CULTURAL/

ECONOMICAL/ POLITICAL CONTEXTS

Although the special education versus inclusive education debate rages on, it is evident that countries globally have struggled to deliver system wide inclusive reform **(Haug, 2017)**. In some nations, where education systems are less developed and/or resources scarce, the provision of special education for students with disabilities may not be viable, and therefore the principles of inclusive education guide the work being undertaken to improve the educational provision for students with disabilities. Paradoxically, it is nations with well-established schooling systems that have experienced significant challenges with the implementation of effective inclusive practices as they operate within 'inflexible twentieth-century education system … built with only particular students in mind' **(Graham, 2020, p. 20)**. To ensure progress towards an inclusive and

... even in fragile and challenging contexts, inclusive education has become increasingly recognized as the standard for countries to achieve.

equitable quality education for all **(SDG 4)**, governments globally must commit to 'a process of systemic reform embodying changes and modifications in content, teaching methods, approaches, structures and strategies in education' **(UN, 2016, para. 11)**. Until that time, special education settings will continue to provide a specialized level of access and support that is not currently afforded consistently across local schools.

The UN Declaration of the Rights of the Child, UN Declaration on the Rights of Disabled Persons and SDG 4 ('inclusive and equitable quality education') provide guiding principles and agreements for inclusive education globally. Countries may experience challenges in achieving inclusion due to reasons such as economic poverty, civil war or natural disaster. However, even in fragile and challenging contexts, inclusive education has become increasingly recognized as the standard for countries to achieve **(Amor et al., 2019)**.

Inclusive education was included as a right under Article 24 of the Convention on the Rights of Persons with Disabilities (CRPD) **(UN, 2016)** and superseded the earlier conception of the right to education. The 'Thematic study on the right of persons with disabilities to education' by the United Nations High Commissioner for Human Rights left no room for doubt: 'the right to education is a right to inclusive education' **(UN, 2013, p.3)**, something that was thoroughly addressed in General comment No. 4 on the right to inclusive education **(UN, 2016)**.

6.6 **.2** **.1**

INCLUDING ALL STUDENTS IN LEARNING

Ensuring all students have the opportunity to learn is more important than ensuring all students are educated in the same physical space **(Imray and Colley, 2017; Kauffman et al., 2018)**. Inclusive education and special education is not a dichotomy; it is a continuum. The most important concern is the best education for individual children. Most of the time that is in a general education

Ensuring all students have the opportunity to learn is more important than ensuring all students are educated in the same physical space.

classroom. However, there is the need for specialized help in some situations and, in that case, there should be appropriate withdrawal from the general classroom. Importantly, there is a dearth of evidence on effective education approaches for children with disabilities **(Singal, 2017; Slee, 2018b)** and a need to collect both quantitative and qualitative data on the learning experiences of children with disabilities globally **(Gorgens and Ziervogel; Kuper et al., 2020)**. Future research must be participatory and recognize a diversity of views, especially those of people with disabilities **(Singal, 2017)**. One study found that, in Kenya, Zambia and Uganda, many people with disabilities had experienced both mainstream and special education and individual preferences varied **(Horton and Shakespeare, 2018)**. Some found special schools hugely beneficial

and appreciated having their physical needs accommodated as well as having the opportunity to meet other people with disabilities. Others felt that being segregated from mainstream education, and sometimes separated from their families, had negative repercussions. Furthermore, the majority of respondents reported experiencing some form of discrimination or barriers to participation in mainstream schools. It is not sufficient to allow children with disabilities to attend mainstream schools, they must be able to fully participate in learning without suffering any discrimination. More ethnographic case studies are needed to better understand the experiences and educational attainment of children with disabilities **(Slee, 2018b)**.

6.7

Future directions: how can education help all learners reach their full potential?

In this chapter, we have assessed research on identification and intervention for learning disabilities. The contributions in this chapter provided an overview of the current state of the art and controversies surrounding the classification of learning disabilities and provision of special and/or inclusive education to support students with learning disabilities. The insights from this chapter and directions for future research can be summarized in the following key findings and recommendations.

6.7 .1

KEY FINDINGS

- Definitions of 'disability' are contentious, and terminology is confusing. In many places, disability is a legal and medical term, and it is important to note that often a diagnosis is required for accessing support services.

- Learning disabilities arise through a dynamic interplay of biological and environmental

Children need, and have the right, to receive help regardless of what has caused their learning difficulty.

factors and therefore are seldom attributable to a specific cause or are only present in children with low cognitive abilities. Children need, and have the right, to receive help regardless of what has caused their learning difficulty. Moreover, there are far more people who struggle with learning than have been diagnosed with a specific disability.

- Research has largely focused on understanding specific reading disabilities, such as developmental dyslexia, yet there are similar prevalence rates among children who have reading, maths and writing learning disabilities that significantly impact their quality of life. Many children with specific learning disabilities have co-occurring neurological and mental health disorders.

- There is a clear lack of research in the Global South on inclusive education and the experiences of children with a disability in various education contexts.

- Despite a global acknowledgement of the importance of a more inclusive approach to education, the ways and extent to which learning disabilities are identified vary across, and even within, countries.

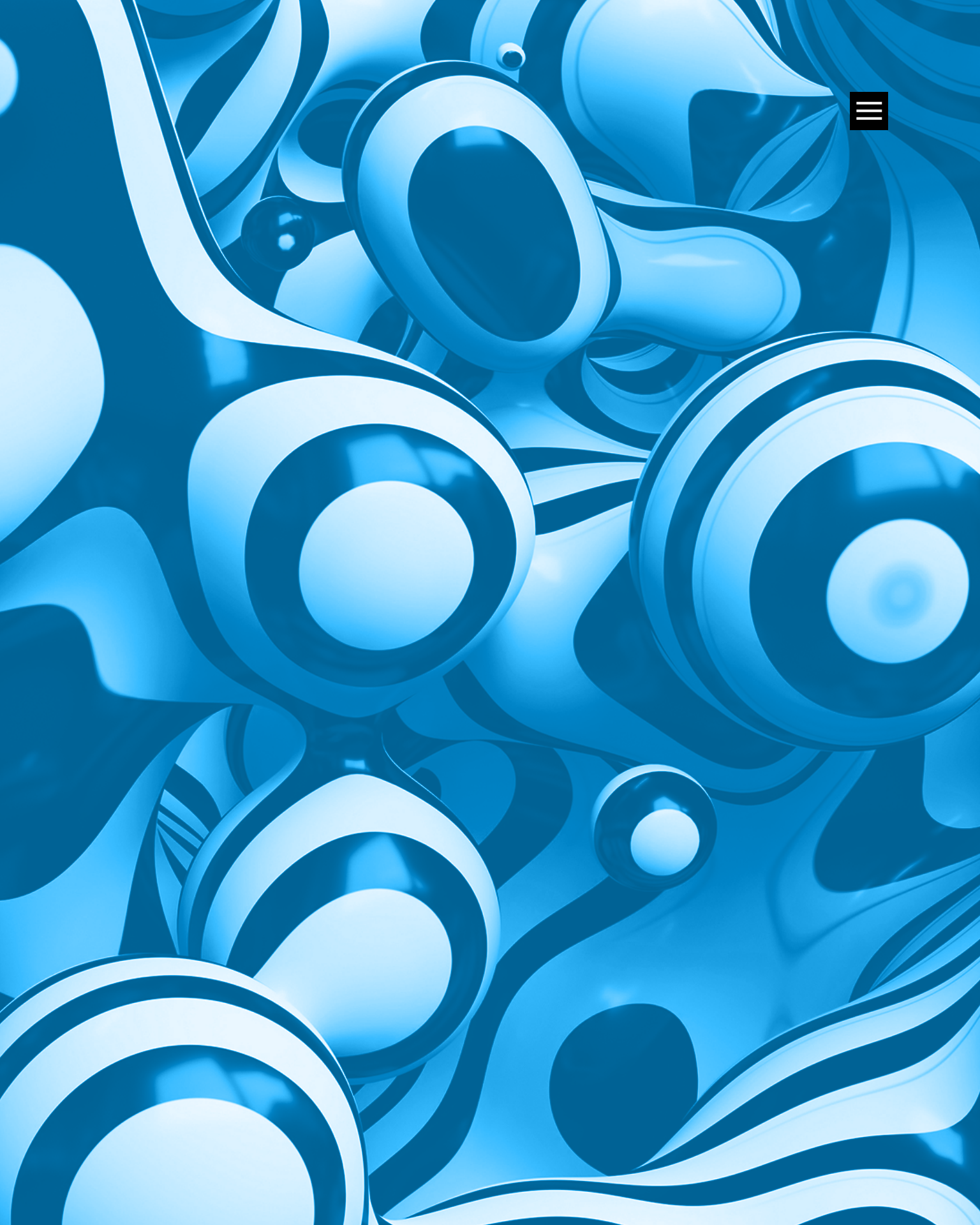- Universal screening and assessment can help identify targets for prevention and remediation.

- Interventions such as high dosage tutoring and some assistive technologies have evidence of effectiveness; however, there is a dearth of evidence on the effective educational approaches for children with learning difficulties.

Greater investment is needed to fund large-scale research studies to determine the culturally-specific infrastructure required for successful implementation of universal screening and evidence based response to screening as well as (intensive) intervention.

6.7 .2

RECOMMENDATIONS

- Universal screening of skills that predict academic achievement could help identify children at risk for learning disabilities.

- Early intervention and monitoring of progress is needed and significantly impacts academic and mental health outcomes.

- Greater investment is needed to fund large-scale research studies to determine the culturally-specific infrastructure required for successful implementation of universal screening and evidence based responses to screening as well as (intensive) intervention.

- Regular monitoring of basic skills to determine whether or not there are problems is required.

- Improving teacher education and training teachers to implement screening tools could help make universal screening feasible. However, it is important to implement an adequate evidence based response to screening.

- Parents can be powerful advocates for their children through parent–school partnerships.

- How can inclusive education truly be effective for all students? Guidelines should be developed to help determine whether different school systems meet the needs of each of the students they serve. Equal education for all does not mean identical education for everyone.

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CHAPTER

7

Learning spaces: Built, natural and digital considerations for learning and learners

This chapter should be cited as:

The goal of this chapter is to assess research that can inform understandings of places and spaces of learning. The chapter assesses evidence across three types of learning spaces: built spaces, digital spaces and natural spaces. It looks at the role of these different kinds of spaces for learning, attainment, interpersonal relationships, skills development, well-being and behaviours – across four pillars of learning to know, to be, to do and to live together. The chapter also explores how learning spaces can be actively shaped, felt and understood through practices and policies that occur within and around them.

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7.1 Introduction

The goal of this chapter is to assess research that can inform understandings of spaces of learning. In addition to legislated formal schooling, different kinds of educational settings and experiences have become embedded in people's daily lives around the world **(Sefton-Green, 2013)**. To some extent, all forms of collective and organized activities for children and young people are 'educational'. People learn everywhere, including in what have been termed formal, informal and non-formal 'learning environments' **(e.g. Eshach, 2007)**. These learning spaces are connected to learning contexts such as primary and secondary education, including home - schooling and alternative formats, higher education and community-based and non-profit organization learning provision. The fact that such provision is often funded not only by governments, but also via philanthropy, civil society and other kinds of welfare provision **(Poyntz et al., 2019)** means that who gets to define and evaluate what counts as learning (and learning spaces) is not straightforward.

While building on the work that has been done on 'learning environments' **(e.g. de Kock, Sleegers and Voeten, 2004)** what is distinctive about this chapter is that it specifies 'environment' as a spatial category. As an entry point,

People learn everywhere, including in what have been termed formal, informal and non-formal 'learning environments.

learning 'spaces' are understood to be the built and 'natural' sites in which learning occurs. However, as many human geographers have argued, physical spaces are not simply containers for human action; they cannot determine learning in a singular or simple way; and physical spaces do not exist in a social vacuum, somehow separate from the action that happens 'in them'.

Space can be understood as the ways in which geography shapes social relations and practices, connecting things and people **(e.g. Lefebvre, 1991; Massey, 2005).** This is sometimes called 'spatiality' **(Keith and Pile, 1993)**, which identifies the coming-together of the physical and the social in different ways across more localized places, such as through migration, technology, or other aspects of mobility in and across land, cities and continents. In thinking about this in relation to education, this means attending to the role and characteristics of particular places of learning, but also the connections (and

divisions) present and enabled among them, for example, as learners move between home and schools, migrate to new countries and communicate with others and with information from across the globe. While having physical (or material) characteristics, places are also shaped and imbued with social meaning culturally, historically and spiritually, as well as spatially connected and influenced by places elsewhere. This combined sociomateriality of places is centred on relationships, among people, with the built environment and other species, and with the land and its histories and future possibilities. While often taken for granted as a backdrop for human activity, place plays a central role in the shaping of human interactions, philosophies, belief systems and actions. Thus, a spatial perspective is important in education, but in some approaches it has not been explicitly considered as a component of learning. In this chapter, we focus on assessing research on learning spaces.

... sociomateriality of places is centred on relationships, among people, with the built environment and other species, and with the land and its histories and future possibilities.

It is also important to note how this chapter frames learning. The chapter includes a wide variety of research on: (1) explicit, visible and measurable learning, such as prioritized in curricula or measured through assessment outcomes; and (2) implicit or hidden learning that extends beyond the explicit curricula of education. This means that the chapter addresses the link between learning and spaces in two ways. Firstly, the chapter makes reference, where relevant, to aspects of the pillars of learning outlined in the **Delors Report (International Commission on Education for the Twenty-first Century, 1996).** In other words, we consider how learning in spaces includes and extends beyond academic learning to also include important elements of social and emotional learning (SEL), such as learning to know, learning to do, learning to be and learning to live together. The extension of these pillars into corresponding and interrelated areas of cognitive, socioemotional and behavioural learning is also

relevant for the work that is outlined in this chapter **(UNESCO, 2015)**. This includes, for instance, where school classrooms are designed to prompt certain kinds of interactions between children that foster ways of living together, or where learning outdoors can teach ethical ways of being with the natural world. The chapter assesses how learning spaces can enable or inhibit these pillars and areas of learning and their associated educational outcomes (e.g. academic knowledge, citizenship and values, behavioural and action competences, social and emotional skills).

At times we have used the specific UNESCO pillars and domain terms for learning, while in other places we have indicated where these terms overlap or are cognate with other descriptions of learning from within specific fields. This is particularly the case where there may be an over-emphasis in these framings on orientations from the Global North **(Sharma, 2018)**. As such, this assessment

> **... a spatial perspective is important in education, but in some approaches it has not been explicitly considered as a component of learning.**

chapter also considers the ways in which learning spaces and places are experienced, constituted, and practised differently across varying identities, cultures and geographies, including in relation to the Global North and South, and by indigenous and non-indigenous learners. This is important as it points to not only the diversity of learning spaces and experiences, but also the ways that inequity and colonization can be part of the geographies of education **(Haluza-Delayet al., 2009)**. One way we might think about this is to look at how categories such as 'formal' and 'informal' may mean different things in different places or may simply not be appropriate. For instance, we want to be particularly cognizant of not equating formal education with classrooms, particularly because doing so may not tally with approaches outside of those dominant in the Global North. To ensure that this chapter does not only discuss learning sciences from the limitations of the Global North, we include authors and

theories that speak to theorizations of learning spaces in and from the Global South **(Connell, 2007)**. Other chapters in this publication look at some of the contextual social, environmental, political and economic factors that affect (particularly) access to learning - including transport, the availability of water/energy and investment in schooling. However, with a focus on learning spaces themselves, this chapter seeks to acknowledge different conceptions and understandings of place (and particularly 'land') that extend beyond western notions of the term − both in terms of the examples and the philosophical perspectives on which we draw, including centering indigenous and Global South scholarship as part of the assessment of existing research in this area.

Secondly, the chapter uses an explicitly geographical frame to help expand the possibilities of what it means to talk about learning, that is, how where you are influences what and how you

learn, in some cases beyond the intended curriculum, assessment or aims of the education. In this chapter this includes, among others:

- the recursive relationship between building design, classroom layout, outdoor or non-built places, and learning technologies (whether analogue or digital) and the curricula and values of the societies in which they are located;

- the experiential and immersive aspects of formal and non-formal learning, including new forms of technological augmentation;

- the ways in which digital, outdoor or 'alternative' learning spaces might seek to reconfigure both the sites and processes of more 'traditional' forms of education.

Driven by a focus on the importance of space and place to learning, the chapter draws in part on a body of work by historians that has traced the evolution of (especially) school buildings

since the nineteenth century, and the ways in which changing school architectures reflect changing views of education and vice versa **(Burke, Cunningham and Grosvenor, 2010)**. However, with an interdisciplinary remit, it also extends that historical work through an assessment of contemporary learning spaces and issues, including through contributions from fields such as indigenous studies, neuroscience and psychology, sociology, and sustainability studies. It also broadens the scope by extending to spaces beyond the Global North, and to learning spaces beyond school architectures – specifically digital spaces and land and the natural environment.

Finally, we note that this chapter was not based on a systematic review, but rather was topic driven based on the identifying contributing authors with key expertise to write short syntheses of research on learning spaces. As such, this chapter is an expert-based appraisal of the current

research landscape. While this process could be described as 'subjective', it draws on the contributing authors' extensive engagement in their areas of study. Contributors have taken care to include references to scholars whose work is robust, while also from groups that continue to be marginalized in academic referencing (e.g. women, People of Colour (POC) and/or scholars from outside Europe/the United States (USA)).

Broadly, the contributing authors used a combination of online searches, manual searches of authors' own resources, and follow-up searches in bibliographies of works cited. Contributing authors undertook the following specific steps to locate relevant and appropriate literature: (1) used keyword and search string strategies in a variety of databases (e.g. EThOS, JSTOR, Scopus, ProQuest); (2) referred to a mix of academic and grey literature; (3) where available, aimed to synthesize insights from

systematic reviews, meta-analyses or narrative reviews; (4) attempted to provide a balanced account of the state of their fields while prioritizing highly influential contributions (e.g. high number of citations relative to publication date); and (5) oriented the selection of literature towards combining general overview research, and more specific case studies and/or topical focus within a broader field.

The rest of the chapter highlights a range of established and nascent research related to the effects and effectiveness of learning spaces (for instance in terms of learning, assessment, behaviours, human and planetary well-being, friendships and belonging). However, given the complex causality between learning spaces and these outcomes, we urge caution in drawing overly simplistic conclusions about the relationship between, for instance, classroom design and learning outcomes.

7.2 <u>Key questions addressed in this chapter</u>

What is the role of learning spaces in education? In other words, how does where we learn affect what we learn through education? This is considered in three subsections.

1. what is, or what can be, the role of built spaces in learning?

2. what is, or what can be, the role of digital spaces in learning?

3. what is, or what can be, the role of natural spaces in learning?

7.3 [Key findings]{.underline}

The chapter assesses the state of research through three domains of 'learning spaces': built spaces, natural spaces and digital spaces. Within each, we identify and assess key trajectories of research and provide examples from different styles of education and types of provision (e.g. formal, informal, non-formal, alternative). Given the embeddedness of built environments on land and with digital spaces, we also point to ways that these three types of learning spaces interact with each other in shaping overall learning experiences.

Although education spaces exist outside those sites designated as 'schools', the vast majority of research on built educational spaces has focused on schools and school buildings.

7.3 .1

BUILT SPACES

| 7.3 | .1 | .1 |

INTRODUCTION

Our assessment in this area indicates increased attention in academic research to the ways in which built spaces can influence educational outcomes. Indeed, the OECD is undertaking an ongoing programme of consultation around 'Effective Learning Environments' **(OECD, 2013)**, by which they mean built learning environments. The research literature shows that school and other physical spaces can affect learning, including attainment, engagement, perceptions of student–teacher interactions, interpersonal competencies, well-being and behaviours (i.e. across all four pillars) **(Blackmore et al., 2011)**. However, as Blackmore et al. **(2011)** also indicate, causality between the design of physical spaces and outcomes is hard

to clearly determine (given the presence of multiple other factors), and in some cases robust and/or internationally comparative evidence is lacking.

This section therefore begins with a general overview of the existing evidence of how built environments (may) affect learning – both from the perspective of architects' and designers' aspirations, and the evidence around outcomes. It then adopts a broader view of the relationship between built design and learning, examining how social practices may interact with built design in shaping educational experiences. It explores learner participation in school design as a specific form of 'learning to do', and the experiences of learners and teachers themselves. Although education spaces exist outside those sites designated as 'schools', the vast majority of research on built educational spaces has focused on schools and school buildings. The notion of built spaces can be extended to designed aspects of playgrounds

and outdoor settings **(these are reviewed in more detail in section 7.3.3)**. Where appropriate, evidence from other settings is reviewed, although this is more limited.

7.3	**.1**	**.2**

BUILT LEARNING SPACES AND THE INTENTIONS OF THEIR DESIGNERS

This subsection examines research that has focused on the intentions of architects and other built environment professionals for learning spaces. It is important to recognize that any connection between the built environment and learning starts with the ways in which aspirations for learning are, effectively, 'built-in' from the very design stage. Evidence in this area is based on a series of important, large-scale, systematic projects although is limited to the twentieth century, mainly to school architecture, and, largely, to the Global North. This is linked to the emerging field of learning spaces research in higher education that has focused on the design, evaluation

and management of learning environments in universities **(Ellis and Goodyear, 2016)**. Starting with schools, these projects set out a series of key issues and challenges for learning space design that are expanded in subsequent sections of this chapter (divided here, as in most research, between evidence from the Global North and Global South). In addition, some examples of the research literature on the intentions of the built environment of other types of learning spaces is included at the end of the section.

School architecture has a fairly recent history. While 'schools' may have been housed in a range of buildings, by the end of the nineteenth century mass compulsory education had become established across the industrialized nations of the Global North. The global reach of the classroom as the basic component of schooling was also established if not yet achieved. School architects were generally employed by the nation-state and designed schools according to contemporary educational principles and norms **(Burke and Grosvenor, 2008)**.

While 'schools' may have been housed in a range of buildings, by the end of the nineteenth century mass compulsory education had become established across the industrialized nations of the Global North.

A significant driving force behind much twentieth century school design, especially in the minority Global North, was the idea that school buildings could promote good health and physical well-being.

A key, overarching feature of early school design was international knowledge exchange. Architects engaged in school design used study tours of varying lengths of time, scope and intensity to inform themselves of what was considered best practice in the wider world. For instance, British architects visited North American cities to determine the best school forms for the growing metropolis **(Burke and Grosvenor, 2013)**. Most famously, architects David and Mary Medd from England spent an entire year travelling around North America visiting schools and meeting with educationalists **(Burke, 2013)**.

A significant driving force behind much twentieth century school design, especially in the minority Global North, was the idea that school buildings could promote good health and physical well-being. For instance, architects collaborated with medical specialists in determining that buildings should be well ventilated. In Europe, the first 'open-air' schools were designed with removable walls from the 1890s. In the decades after the 1940s, architects working for the United Kingdom Ministry of Education made detailed measurements of children in school buildings calculating the reach of their limbs and their sight-lines so that scaled fittings and furnishings could best be designed for learning.

From the 1950s onwards, the urgent need to reconstruct school buildings across Europe coincided with a concern to examine how architects could enhance the strengthening of democracy through education. In Italy, for example, the preschools of Reggio Emilia emphasized through design how the building could have agency as a teacher. In England, efforts to open up and make use of all spaces in schools beyond the traditional classroom came to influence architects across the world, and especially in 'alternative' education settings such as Steiner schools **(Kraftl, 2006)**. In these settings, architects and teachers attempted to experiment with 'traditional' Western classroom layouts – for instance, in the creation of more 'home-like' environments in

Steiner kindergarten through the use of soft furnishings and a circular floor plan, and through the use of highly organized learning materials (by size, colour and purpose) in the Montessori classroom **(Kraftl, 2013)**.

In the past thirty years, architects and built environment professionals active in the field of learning environment research have historically been informed by environmental psychology and 'person-environment fit' studies (and latterly emerging work in the neurosciences), with the purpose of evaluating the impacts of built spaces on learning outcomes **(Fraser, 1991)**. There has been an emphasis on recording the measurable sensory qualities of internal environments. For instance, Barrett et al. **(2015)** propose three principles that should therefore inform school design: naturalness (light, sound, temperature, air quality and links to nature); individualization (ownership, flexibility and connection); stimulation (appropriate level of complexity and colour). The relationship

between school buildings and learning here is conceptualized as directly impacting the brain's functioning **(Barrett et al., 2015)**. Learning is understood in this context as the rate of academic progress based on formal pupil achievement.

There is also more limited evidence about school design principles and aspirations from the Global South. Although learning spaces pre-existed colonial rule, much of the historical research on such sites starts with the colonial period, in particular because of the ways that European notions of education and 'school' were imposed. Additionally, many countries in the Global South have an historic legacy of colonial school buildings, which persists into the stock of contemporary school buildings and more generally into approaches to learning space design **(Uduku, 2018)**. The oldest were built more than a century ago by missionaries who made education and schooling essential to Christian conversion **(Fafunwa and Aisiku, 1982)**. There are examples of the mission school across the world, particularly in

The relationship between school buildings and learning here is conceptualized as directly impacting the brain's functioning

Teaching and school design up until the post-Second World War period thus were modelled on European educational standards.

India, Africa and Latin America. Often these early schools and classrooms were first built using locally obtainable materials and to the specifications of missionary building handbook formats, centred upon Christian educational principles **(Waddell, 1970)**. The missionary-developed design guidelines for these schools were further standardized by colonial governments, as in the case of schools in former British colonies, to create colonial school design standards **(Uduku, 2018)**. Until 1945, the funding for colonial schools was linked to grants in aid and all schools (government, private or missionary run) had to comply with a number of criteria, including design standards, successful examination pass rates and teacher qualifications, to receive this funding **(Ajayi, 1969)**. Teaching and school design up until the post-Second World War period thus were modelled on European educational standards.

From the post-war period, with the involvement of international organizations such as UNESCO and the World Bank, school design in the Global South became more international in its standardization **(e.g. De Raedt, 2014)**. United Kingdom (UK) and United States (US) educational facilities researchers collaborated in the production of the UNESCO school building guides **(Uduku, 2018)**. These UNESCO offshoots developed design guides related to local climate conditions and encouraged construction using local materials and the design of child-scale school furniture, as well as the initiation of child-centred learning. For instance, in Nigeria, the demonstration schools project was developed by a Nigerian firm in association with UNESCO consultants and produced climate sensitive school designs across Nigeria's climate zones **(Uduku, 2018)**.

The collapse of many Global South economies from the mid-1970s to 1980s meant that most classroom design did not evolve as had been hoped, often deteriorating in quality with a lack of investment. However, so-called 'aid' built schools have,

since that period, tried to address these challenges, particularly in rural contexts **(Amin, 2014)**. More recently there has been a more concerted effort by international organizations and (NGOs) to address the need for education as a Millennium and now Sustainable Development Goal. The key emphases here have been on school design that is sensitive to local intersections of climate, culture, natural materials and contemporary teaching methods **(Uduku, 2018)**.

As a result, significant evidence shows that school buildings are not and have never been merely containers for learning – they relate to their surrounding communities in a range of ways. In other words, there is considerable evidence that the 'external' relationships (some involving different forms of informal and formal learning) are just as important as the 'internal' relationships that buildings foster **(Collins and Coleman, 2008; Holloway and Pimlott-Wilson, 2011; Kraftl, 2012)**. As defined above, the geographical concept of 'spatiality' offers a lens through which to understand

these broader sociospatial processes. These approaches need not be detached from studies of the internal, material details of school buildings; indeed, key studies (including those cited above) have examined how the material properties and arrangements of objects in schools have fostered specific learning relationships that are embedded in pre-existing social relations, such as computer suites that assume individualized learning, and the building-in of neoliberal educational ideals into school building programmes **(McGregor, 2004, p. 356; Kraftl, 2012)**. Others have addressed issues such as the wider role of the school aesthetic in advancing (both within and beyond the 'school' community itself) forms of surveillance, and citizen formation, reproducing dominant economic ideologies and constituting urban relations **(Gulson and Symes, 2007; Pykett, 2009; Christie, 2013)**.

Moving to the present day, a further important finding stemming from studies such as those above is that despite

The key emphases here have been on school design that is sensitive to local intersections of climate, culture, natural materials and contemporary teaching methods.

7

CHAPTER

Education, like architecture, has become increasingly marketized, with schools distinguishing themselves visually and commercially, and calling on architecture for assistance.

strong international trends in educational architecture, school design is tied closely to national and international shifts in political economy. Where neoliberal governance has been strongest, for example, the social ambitions of both architecture and planning have shrunk, via different mechanisms. Profession-wise, architects' capacities for effecting real change have been curtailed through downgraded statuses and fewer, reduced roles in public building procurement. Education, like architecture, has become increasingly marketized, with schools distinguishing themselves visually and commercially, and calling on architecture for assistance **(see Rowe, 2017, pp. 136-137** for discussion of Australian schools and architectural brand-management). In the design professions more generally, a 'tendency to abdicate from futuring' **(Tonkinwise, 2015, p. 88)** means disengagement from 'big' issues, such as social inclusion.

Meanwhile, particular social and political issues have become explicit – more urgently and clearly social problems

requiring spatial responses. For example, Uduku **(2018, p. 118)** has shown how post-apartheid, racial integration in South Africa necessitated new school building design guidelines and, for primary schools, increases in net space to accommodate schools' extended roles as centres for feeding programmes. In the USA, Erickson **(2016, p. 563).** has explored planners' and educationalists' joint work designing vast educational campuses aimed at encouraging desegregation by drawing on students across multiple, racially- and economically segregated city zones.

Although smaller in scope, there has been an increasing focus on the built learning spaces of universities and other forms of higher education. These emerging literatures have responded to trends – especially in the Global North – towards increased investment in the built environments of (particularly) university campuses **(van Heur, 2010).** The imperatives for such innovation are diverse but

> **Although smaller in scope, there has been an increasing focus on the built learning spaces of universities and other forms of higher education.**

centre on the marketization and neoliberalization of University education – as campuses are seen as key 'selling points' to attract students and as nodes for urban and regional innovation **(van Heur, 2010)**. Significantly, although including investments in spaces such as lecture theatres and libraries, these intentions often extend beyond the specifics of learning to the commercial functioning and roles of universities **(Amcoff, 2020)**. However, as evidence in the next section attests, the (re) development of campuses is also related to different domains of learning – both in terms of its effects on and support for, more flexible, less didactic kinds of learning interactions, and in terms of the creation of cultures and communities of learning **(Temple, 2009)**. Significantly, many studies focus on the latter – how campus spaces can be turned into places of learning that attempt to (literally) concretize the aspirations of universities for the kinds of learners they want to produce, with a focus on capacities such as flexibility, innovation, creativity,

sustainability and individual responsibility **(Berti, Simpson and Clegg, 2018)**.

There is also a wide range of literature that considers the intentions of built learning spaces beyond primary to higher education. For example, there is quite extensive research on the learning contributions of built religious environments. Vosko **(1991)** writes about his work as a designer of religious spaces for adult learning, including undertaking 'audits' of the environmental factors of built religious spaces in terms of their implications for participation and congregational learning. Considerations in these learning spaces include invoking a sense of hospitality through building materials, lighting, temperature and ensuring physical accessibility for all. Vokso **(1991)** also discusses shifting relationships between teachers and learners in religious settings, often with a move away from environments set up for the dispensation of knowledge, and instead providing rooms and seating arrangements aimed at

Additional areas that have considered the built environment across a range of ages and learning dimensions include community centres, libraries, zoos, aquaria, science centres, botanic gardens and museums.

mutuality and collaboration **(see also WG2-ch8)**. Other factors such as sightlines, use of digital media and signage are also considered aspects of built religious environments that maximize participation and learning. In reviewing work in Jewish education, Lynn-Sachs **(2011)** discusses synagogue based education relative to other spaces such as Jewish day schools and preschools, camps and community centres; and comparing the features of these spaces to congregation based Christian education, and secular schools. Other researchers have also documented the mirroring of synagogue schools to the institutions of public schooling throughout the twentieth century **(Cuban, 1995; Weinberg, 2008)**. Additional areas that have considered the built environment across a range of ages and learning dimensions include community centres, libraries, zoos, aquaria, science centres, botanic gardens and museums (e.g. Gupta et al., 2019; Cole, Lindsay and Akturk, 2020; Hassinger-Das et al., 2020). Due to the scope of this literature, in the following

sections on particular learning outcomes related to built spaces, we focus in particular on primary to higher education learning environments.

7.3 .1 .3

EVIDENCE ABOUT HOW BUILT ENVIRONMENTS AFFECT COGNITIVE LEARNING OUTCOMES FOR SUBJECT-BASED ACADEMIC KNOWLEDGE

Whilst the intentions of architects are an important starting point for assessing the relationship between the built environment and learning, those intentions – and the experiences of learners – are also based on evidence about the relationship between physical design and learning outcomes **(Trask and Khoo, 2021)**. In this section we discuss 'learning' in relation to cognitive outcomes and skills **(WG3-ch5)** directly related to intended aims of education, such as those of curriculum, skill and subject outcomes, although there are overlaps with other outcomes such as behaviours (see following section). However,

Large-scale quantitative studies have attempted to evaluate the effects of light, ventilation, colour and flexibility of furniture on student and teacher performance.

it must be noted immediately that evidence about the direct relationship between design and cognitive learning is limited. This is because the connection between learning outcomes and built environment is mediated and complicated by tangibles (e.g. quality and design of ventilation) and intangibles (e.g. school and classroom culture) **(Blackmore et al., 2011; Higgins et al., 2005, p. iii)**.

In terms of primary and secondary schools, conventionally, building performance is assessed against measurable attributes and subjective reports, to optimize conditions for learning. There are several established frameworks such as 'Post Occupancy Evaluation' (POE) and 'Building Performance Evaluation' (BPE). These assessments have been limited due to high cost, although a number of assessment tools have been developed in an effort aimed at standardization (e.g. Organising Framework on Evaluating Quality in Educational Spaces **OECD, 2009)**, Design Appraisal Scale for Elementary Schools **(Tanner and Lackney, 2006))**. Furthermore, their value to users of existing buildings is frequently unclear.

Investment in schools' built environments seeks to create learning spaces conducive to developing desirable learner capabilities of team work, communication, interpersonal and intercultural interaction, emotional and digital literacies **(Filardo 2008; Temple, 2009; Lippman, 2012)**. Yet no significant body of evidence indicates that the quality and design of the building can be causally linked to learning outcomes as measured by standardized assessments **(Higgins et al., 2005)**. Importantly, Blackmore et al.'s **(2011)** literature review found research concentrated on the design phase, with less research undertaken on the educational practices and outcomes that arise.

Large-scale quantitative studies have attempted to evaluate the effects of light, ventilation, colour and flexibility of furniture on student and teacher performance **(Keep, 2002; Lackney and Jacobs, 2002; Higgins et al., 2005; Durán-Narucki, 2008; see the next section)**. Incremental improvement in

> ... naturalness (light, etc.), personalization (flexibility) and stimulation (colour, aesthetics) 'contribute to student progress in learning'.

student achievement is gained when renovating low-or-medium quality built environments is connected with improved attendance, reduced illness and teacher retention, particularly in disadvantaged communities **(Schneider, 2002; Buckley, Schneider and Shang, 2005; Mendell and Heath, 2005)**. These factors can have an impact on school climate, but that effect plateaus at a certain point **(Higgins et al., 2005; Loi and Dillon, 2006; Temple and Reynolds, 2007; Gislason, 2009)**. Recent quantitative studies aiming to 'control' through research design for familial background, type and location of the school and teacher quality provide some evidence that naturalness (light, etc.), personalization (flexibility) and stimulation (colour, aesthetics) 'contribute to student progress in learning' **(e.g. Barrett et al., 2015; Barrett et al., 2019)**. Early childhood studies based on playbased measures of developmental learning find that more natural outdoor environments do improve cognitive, affective and physical outcomes **(Morrisey, Scott and Wishart, 2015)**. However, these studies generally ignore mediating intangible variables such as peer relationships, teacher practice, pedagogy and other school-related factors.

While there is a growing body of evidence on the links between physical environment – aspects such as toxins like lead, and access to clean water – and student development, especially in early years, including cognitive and SEL, the majority of studies relate to the Global North. Nonetheless, an international review of research in this area found that despite a paucity of research, similar issues of links between the physical environment and learning occur in the Global South from water pollution in Mexico to the effects of lead in Egypt on development **(Ferguson et al., 2013)**. A mixed methods study of Ghanian inclusive schools found an urgent need to improve ventilation, and less obvious factors such as colour schemes of walls, in order to better include a diverse range of students **(Ackah-Jnr and Danso, 2019)**. The COVID-19 pandemic has blurred the boundaries between the physical learning spaces of home and formal schooling,

with lack of adequate conditions exacerbated in the Global South. An overview of the South African educational response to COVID-19 shows that many students are severely disadvantaged by lack of appropriate facilities at home, including infrastructure to support distance learning. However, the longer-term effects on learning outcomes are yet to be determined **(Soudien, Reddy and Harvey, 2022)**.

Specific evidence around the introduction of more flexible and/or open classroom spaces is, however, more robust (although this does not mean that these environments are somehow necessarily more effective than 'traditional' designs). Mobile furnishings and technologies can be a catalyst for teacher experimentation to meet students' learning needs by enabling group learning, collaborative peer

> ... it has been found that temperature 'comfort zones' can impact upon students' learning - for instance, extreme cold, heat and noise have negative impacts.

interactions and student agency **(Blackmore et al., 2011; OECD, 2013)**. Personalized spaces can impart a sense of security **(Lee, 2007; Woodman, 2016)**. With a shift from teacher-focused to student-focused pedagogies, critical factors are schoolwide planning for use of flexible spaces, teacher professional preparation, resourcing, building maintenance and serial redesign over time as digital technologies develop **(Clark, 2010; Blackmore et al., 2011; Deed and Lesko, 2015; Woodman, 2016; Imms and Byers, 2017; Blythe, Velissaratou and OECD, 2018)**. However, open learning spaces can increase teacher anxiety if not well prepared and supported **(Saltmarsh et al., 2014; Barrett et al., 2017)** and can have a negative impact in terms of learning outcomes on students with visual, speech or hearing impediments **(Klatte, Bergstrom and Lachmann, 2013)**.

Within higher education settings, there are fewer studies about the relationships between the built environment and cognitive learning. These are similarly inconclusive about the direct effects of (for instance) learning space architectures, light, temperature and other conditions because, as with schools, these effects are complex and combined with a range of other influences. In higher education settings, it has been found that temperature 'comfort zones' can impact upon students' learning − for instance, extreme cold, heat and noise have negative impacts **(Marchand et al., 2014)**. However, as with several studies, these findings are based upon students' perceptions of learning rather than standardized testing outcomes **(e.g. Sörqvist, Halin and Hygge, 2010; Halin et al., 2014)**. Indeed, Scott-Weber et al. **(2013)** argue that post-occupancy studies of higher education student outcomes in (predominantly) university classrooms are generally lacking. In one of the most comprehensive attempts to address this gap, Scott-Weber, Strickland and Kapitula **(2013)** introduced a three-part methodology − drawing on self-reported engagement factors, secondary data and emerging brain science − finding statistically significant improvements in student engagement as students

moved from old to new, purpose-built classrooms (although the built/designed details of the spaces are not specified in their work). Rands and Gansemer-Topf **(2017)** report similar findings in a separate study. There is also still the issue here that this and other studies rely heavily on student self-report in terms of 'engagement', even if specific engagement factors – motivation, collaboration, focus, feedback – are specified, noting again that these are not only contingent on the built environment **(Temple, 2009; Tampubolon and Kusuma, 2019)**.

7.3	.1	.4

EVIDENCE ABOUT HOW BUILT ENVIRONMENTS AFFECT BEHAVIOUR, HEALTH AND WELL-BEING OUTCOMES

This subsection focuses on assessing the existing research on how primary to higher education built environments may affect student behaviours, health and well-being – in other words socioemotional and behavioural outcomes that may connect with, but also

extend beyond, the specifics of cognitive learning **(WG3-ch4)**. As with cognitive learning outcomes (see the previous section), while environmental quality evaluation frameworks do not systematically assess student well-being, behaviour or experiences, there is some evidence of these impacts. Lopez-Chao et al. **(2020, p. 2)** review a wide range of studies that have, for instance, demonstrated the impact of lighting and noise on children's attention, the effects of thermal changes on problem-solving and the impacts of views of nature (or even green walls) on feelings of restoration, maths performance and vocabulary. They find a positive but complex relationship between maths performance and ventilation, room size, views and place attachment, but that higher chair comfort and thermal comfort actually decrease performance **(López-Chao et al., 2020, p. 10)**. Research tends to ignore the wider range of learning competencies associated with the four pillars of education, as well as a lack of robust methods for evaluating them **(Byers et al., 2018)**.

Over the past decade there have been important developments in the interdisciplinary field of neuroarchitecture …

Nevertheless, recent studies (although largely confined to Australia) have begun to investigate the impacts of flexible learning spaces on health and well-being. In schools that have removed traditional rows and desks and replaced them with more lounge-like furniture and open/break-out spaces, there have been improvements in learning engagement and student well-being **(Kariippanon et al., 2018)**. Attempts to introduce physical activity interventions (e.g. moveable furniture) have led to a positive effect on working memory but no impact on body fat index (BMI) or body fat **(Parrish et al., 2018)**. There is currently much hope and expectation that advances in environmental neuroscience and psychology will provide the necessary insights for school designs that are more nature based, physiologically informed and better for mental health and well-being **(Salingaros et al., 2008)**. However, there is much discipline bridging groundwork that remains to address the gap in understanding of how neurobiological processes link

with environmental drivers of behaviour **(Berman et al., 2019)**. Moreover, flexible spaces do not on their own necessarily improve learning outcomes and more 'traditional' designs may be equally appropriate depending on the curriculum, approach, values and outcomes desired in a particular learning space.

Over the past decade there have been important developments in the interdisciplinary field of neuroarchitecture **(Eberhard, 2009)**, examining the effects of spatial design, building layouts, urban form and aesthetic characteristics on various aspects of human experience, including perception, cognition, well-being, stress, spatial perception, way-finding, memory and behaviour. However, again, there is little evidence that this approach is yet being applied in the design and architecture of school environments, as confirmed by a recent review of the field **(Karakas and Yildiz, 2019)**. There is enthusiasm to develop neuroscientific approaches in learning environment research should the field move beyond the

experimental stage **(Noriega et al., 2016)**.

Finally, in the absence of reliable research about the direct effects of school buildings on learning outcomes (and especially cognitive learning outcomes), there has, by contrast, been a very large body of work on learners' and teachers' experiences of being in physical learning spaces **(Daniels et al., 2019)**. This research has extended across a number of disciplines, but it is most prevalent in human geography – in the so-called 'geographies of education' **(Holloway et al., 2010)** – given a focus in that research on critically analysing the workings of educational spaces, and upon listening to the voices of those doing teaching and learning **(Kraftl, 2020)**.

A key focus in work on the geographies of education has been on the power relations that operate in built learning spaces (and which are perhaps unique to spaces called 'school'). As Kraftl **(2013)** evidences in his work on alternative education, it is the combination of rules, behaviours, uniforms, smells and physical

design (corridors, classrooms, furniture) that makes up what is understood as a 'school'. Indeed, he shows how families who withdraw their children from mainstream schools do so because of the perceived negative effects of the environment on their children **(also Conroy, 2010)**. There is an established body of evidence that has explored how children and teachers experience and attempt to subvert power relations in schools **(Youdell, 2006; Taylor, 2013; Catungal, 2019)**. For instance, Pike **(2008)** examined how children negotiate the micro-spaces of UK school dining halls in order to subvert rules imposed on them about what they can eat, and when, and how they can move around the space **(see Berggren et al., 2020, for a similar Swedish study)**.

A second important body of evidence has focused less on the intended outcomes of built learning spaces for learners than their experiences of those spaces, especially in respect of the development of identities and friendships **(Newman, Woodcock and Dunham, 2006; Holloway et al., 2010; Kraftl et al., 2021)**. Valentine

> A key focus in work on the geographies of education has been on the power relations that operate in built learning spaces.

…'informal' parts of the learning campus - corridors, for instance - are critical places where children and young people negotiate 'narratives of identity' related to bodily size, gender, sexuality and character traits.

(2000) showed how the 'informal' parts of the learning campus – corridors, for instance –are critical places where children and young people negotiate 'narratives of identity' related to bodily size, gender, sexuality and character traits **(WG2-ch4)**. This work has shown how students with certain capacities or bodily traits – such as disabilities – may feel excluded by combinations of built form and expected behaviours that make them feel unsafe, 'different and thus "out of place"' **(Holt, 2004, 2007; Pyer et al., 2010; Holt et al., 2012)**. However, often in conjunction with architects and other built environment professionals, scholars have attempted to demonstrate how such exclusionary forms of design (in association with rules, norms and teaching practices) can be changed to create more inclusive environments. For instance, Newman, Woodcock and Dunham **(2006)** demonstrated how 'nurturing' environments that were less rigid in their design (through the use of colours, soft furnishings and more informal layouts) feel safer and more welcoming to pupils.

There has also been some limited scholarship on the relationship between 'green' or 'sustainable' learning space design and SEL outcomes, with some evidence that 'early attitudes and knowledge [of sustainable design] shape the later thinking of adolescents and adults' **(Leeming, Dwyer and Bracken, 1995, p. 3)**. Indeed, the National Research Council of the National Academies of Science enlisted a group of scholars to investigate the possible relationship between green schools and student achievements and they had difficulty in finding any research available that addressed the topic **(Earthman, 2016)**. However, a key, recent piece of research from Australia – data from 624 children, aged ten to twelve years old, who completed a survey adapted from the New Ecological Paradigm (NEP), and General Ecological Behaviour (GEB) scales for children – has shown that the physical learning spaces of sustainably designed schools can act as pedagogic tools that influence children's environmental attitudes and

> **...children attending schools designed for sustainability had more pro-environmental attitudes and behaviours than children in conventional schools**

behaviours **(Tucker and Izadpanahi, 2017)**. Analyses indicated that sustainable design in schools was a powerful predictor of children's environmental attitudes and behaviours, and that children attending schools designed for sustainability had more pro-environmental attitudes and behaviours than children in conventional schools **(Wake and Eames, 2018, report similar findings in New Zealand)**. The above study corroborates prior research recognizing the impact of sustainable design in schools on children's environmental learning **(Newton, Wilks and Hes, 2009; Cole, 2013)**, and suggests that experiential learning via sustainability features at school, such as such as solar panels, use of recycled water and natural daylight, provides children with the opportunity to be mindful of, and to affect, consumption of energy and water **(Kang et al., 2015)**. Experiential education, such as learning in outdoor classrooms and schoolyard gardening, can also increase students' relationships with nature and their sense of contributing to action on

sustainability issues **(Wake, 2004; Wake and Birdsall, 2016)**.

Meanwhile, literature also reveals contradictory results in cases where green school programmes might not necessarily enhance student sustainability outcomes (consciousness knowledge attitude, behaviour). Some studies found no significant relationship between sustainable building attributes and environmental attitudes **(e.g. McCunn and Gifford, 2012)**. Similarly, Olsson et al. **(2016, 2019)** suggest that investment in a green school project (in their case in Taiwan) had no benefits in terms of sustainability knowledge, attitudes and behaviours among students. The findings indicate that the intended 'education for sustainable development' in schools had a small positive effect on students' sustainability consciousness, while in grade 9, the effect was negative **(Olsson et al., 2019)**.

As with cognitive learning outcomes, research on socio-emotional and behavioural

... key work by geographers of education has highlighted how - particularly for students from minority ethnic and religious groups - the physical spaces of a university campus may be exclusionary.

outcomes in higher education settings is more limited. It also focuses largely on students', teachers' and university managers'/leaders' perceptions of the benefits of (for instance) investment in new buildings **(e.g. Temple, 2009, 2014)**. This research should be interpreted carefully given that critical scholarship on neoliberal university systems has identified how campus investment is often linked to competitive imperatives to attract (fee-paying) students **(Ball, 2012; Breeze, Taylor and Costa, 2019)**. Moreover, the range of 'outcomes' is fairly disparate – from the positive effects of increasing pedestrian walkways on physical activity **(Sun, Oreskovic and Lin, 2014)**, to measures to increase bicycle uptake on campus **(Chevalier, Charlemagne and Xu, 2019)**, to – in one of the most comprehensive studies – the positive effects on self-reported well-being/behaviours of functionality and layout, cosiness and pleasantness, concentration and comfort, and 'modern' design **(Castilla et al., 2017)**. The first two factors – functionality/layout and cosiness/pleasantness – were found to be consistently

the most important for nearly 1,000 students across thirty classrooms **(Castilla et al., 2017)**. Finally, mirroring scholarship on school based power-relations and identities, key work by geographers of education has highlighted how – particularly for students from minority ethnic and religious groups – the physical spaces of a university campus may be exclusionary since they can embody and symbolize majority cultural norms **(Hopkins, 2011; Bunce et al., 2019)**. Meanwhile, several important studies have demonstrated how the campus, halls of residence and purpose-built social spaces are key places at which students develop senses of identity (particularly those learners living away from home for the first time and transitioning to adulthood), belonging and 'home' **(Brooks, Byford and Sela, 2016; Holton and Riley, 2016; Sykes, 2016; Cheng and Holton, 2019)**.

7.3	**.1**	**.5**

INVOLVING LEARNERS AND OTHER STAKEHOLDERS IN LEARNING SPACE DESIGN: PROCESSES, OUTCOMES AND CHALLENGES

This subsection looks at fairly well-established evidence about the processes and benefits of involving learners – especially children – in the design of built learning spaces. Given that the vast majority of available evidence is about school design, this is the focus for the section. After considering different approaches to, and structures for, learner participation in design, it examines the benefits and drawbacks of participation, in a context where it is usually assumed that learners' involvement in design processes is unequivocally beneficial. It also examines some of the evidence about the outcomes of participation for learners – including (although generally less well-established) in terms of learning outcomes.

Children's involvement in school design takes many guises: from

The primary motivations for involving children and the wider school community in the process of creating school spaces differ according to the agenda of those who initiate the process.

informing the vision for major new buildings, extensions or refurbishments; to ongoing, everyday spatial and material adjustments and appropriations in an existing school as part of a participatory school culture[1] **(see also den Besten, Horton and Kraftl, 2008; den Besten et al., 2011; Kenkmann, 2011; McCarter and Woolner, 2011; Chiles, 2015)**. The primary motivations for involving children and the wider school community in the process of creating school spaces differ according to the agenda of those who initiate the process. While child-initiated emancipatory processes might represent a participatory ideal **(Hart, 1997; Chawla, 2001; Fielding, 2001)**, the impetus for a new or reconfigured environment, centred on children's learning, most often emerges from priorities set by adults.

Government-initiated school design and construction programmes have sometimes identified involvement of the school community as a requirement, citing the need for engagement as a means to achieve

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[1] http://www.designingwithchildren.net/ http://www.designingwithchildren.net/

higher quality school buildings, offering educational benefits to the students involved and a sense of ownership for the wider school community **(Heppell et al., 2004)**. Individual schools extending or renewing their physical spaces have also initiated processes of engagement, commissioning design teams that prioritize user participation **(e.g. Sanoff, 1999; Hubner, 2005; Yanagisawa, 2007; Jilk, 2009; Hofman, 2014; Chiles, 2015)**. Significantly, some school buildings would not be realized without the vision, commitment and voluntary labour of the local community. In community development and humanitarian aid contexts, a school building might be built by volunteers from the school community, often including children in that building process, alongside international volunteers **(Narea, 2017; Fan and Tanoue, 2019)**. Such construction sites have also become contexts for skills training and capacity building, sometimes

also formalized through links to further or higher education **(Cuevas, 2018)**.

Also underpinning approaches to participatory design are attempts to challenge (European) norms of architectural practice and power. In the Canadian context, the concept of 'design sovereignty' recognizes the danger that indigenous forms of built learning spaces are exploited by designers and architects, and that the only way to counteract this is through the appointment of indigenous people as lead architects (currently only 18 out of 10,000 registered Canadian architects are indigenous) **(Fortin, 2020, p. 243)**. This principle of self-determination could be applied across other forms of exclusion from design of built learning spaces. For example, in Northern Ireland, McAllister and Sloan **(2016)** involved young people aged 13–18 with autism spectrum condition (ASC) in a school design study to instruct designers on what they thought made up an autism-friendly environment, recognizing that a person's

interaction with their environment is not always a positive one and that the experiences of children with ASC regarding playgrounds, security, noise, comfort, circulation round the school, simple legibility of space and breakout space should be built into school design.

The structural constraints on education as a context for participation mean that it is important to also consider speculative, exploratory design activities with children to be a part of the wider 'School Participation Project'. Competitions such as 'The School I'd Like' in the UK **(Burke and Grosvenor, 2003)**, and similar contests in the USA and Australia, have invited children to rethink the relationship between physical space and learning. School design projects that invite children's involvement are almost always of low priority when it comes to establishing such fundamental principles. Some critics would therefore argue that participation in this context can only ever be limited to influencing relatively token decisions about space, materials and use, never

Also underpinning approaches to participatory design are attempts to challenge norms of architectural practice and power.

... a wealth of positive impacts and benefits associated with learner participation in school design are identified.

really challenging assumptions about education, learning and space **(den Besten et al., 2011)**. Notwithstanding these limitations, a wealth of positive impacts and benefits associated with learner participation in school design are identified.

Most school design participation activities by children are framed in developmental terms and linked to the formal curriculum. Learning activities can build upon or use the school design project as a resource linking to almost any subject area. The benefits of this approach lie in the school building project becoming a 'worked example' in learning **(JIA, 2020)**. Learning and achievement are aided by providing 'first-hand, relevant experiences that contextualize learning.' **(Kendall, Muirfield and Wilkin, 2007a, pp. 17-18; Kendall et al., 2007b)** Interactions between the design or construction team and the students can offer inspiration as well as insight into possible professions **(Sutton and Kemp, 2002)**. Students have also been shown to learn technical knowledge relating to building and architectural principles, including materials,

structure, construction and sustainability **(Parnell, Cave and Torrington, 2008)**.

Beyond the subject based curriculum, there are many overlaps, firstly, with the benefits of art and design education and, secondly, with voluntary activity and enterprise education. Participants and their teachers commonly perceive improvements related to creative development – such as capacity to experiment, take risks and problem-solve – and improvements related to aspects of personal and social development – such as self-confidence and self-esteem, communication skills and working with others **(The Sorrell Foundation, 2006; WG1-ch4; WG2-ch8; WG3-ch4)**. Wider education-related benefits include motivation to learn, improved behaviour, enjoyment of school and ability to learn independently **(for summaries of reported benefits see Bentley, Fairley and Wright, 2001; Sorrell and Sorrell, 2005; Parnell, Cave and Torrington, 2008, Deveson, 2008)**. A few studies have related pupils' participation in the design of school buildings to improvements in their

academic achievement, attendance and behaviour, although Day, Sutton and Jenkins **(2011)** point out that this claim has been disputed elsewhere **(Sutton and Kemp, 2002)**, as with other studies of the relationship between school design and learning (see earlier section about how built environments affect cognitive learning outcomes for subject-based academic knowledge).

The sense of environmental competence that can be developed through place making activity has been linked with increased well-being resulting from children's improved abilities to exercise control over their environments (connected with their wider rights as children, as enshrined in the United Nations Convention on the Rights of the Child), and to derive health and educational benefit **(Day et al., 2011, p. 51)**. School participatory design processes have provided student participants with opportunities to develop collaborative, cooperative and dialogic relations with other actors, resulting, in some instances, in the development of empathy and open

communication skills. Adult–child relations have also been shown to adjust, with the attitudes of both staff towards students and students towards staff taking on a new form; each seeing the 'other' not in their role, but as 'more human' **(Parnell, Cave and Torrington, 2008)**.

Perhaps the most fundamental rationale for children's involvement in school design is that it will lead to more appropriate spaces, ultimately therefore improving children's comfort, well-being and the inclusiveness of experiences of school and learning. The task of examining and evidencing such relationships, however, is complex to the point of being prohibitive (in parallel with attempts to evidence the relationship between built space design itself and different learning outcomes (see preceding sections). One of the common effects of school community engagement during the design phase, however, is a sense of ownership among diverse participants **(Higgins et al., 2005)**. Whether this is due to the process or the resulting product is difficult to ascertain. However, children's

experiences and perspectives often differ greatly from those of the adults who are tasked with designing the space that they will inhabit – not least due to obvious physiological differences. It follows then that architects and designers who have engaged with children in the school design process have reported that they have gained knowledge, insights and 'ways of seeing' that have informed their spatial design and of which they would otherwise have been ignorant of **(Sorrell and Sorrell, 2005, p. 60; Clark, 2010; Hofmann, 2014)**.

All of the above potential benefits and positive impacts of school design participation are dependent on positive and appropriate processes. Badly implemented and disingenuous processes of involvement have been shown to provide contexts for coercion and manipulation, or have simply wasted participants' time and effort by being ineffectual, resulting in negative attitudes and participation fatigue. The benefits of involvement in school design and re-design are by no means guaranteed, and careful attention needs to be paid to the implicit

politics in architecture and spatial organization **(den Besten et al., 2011; Kraftl, 2012)**.

BOX 6: SUSTAINABLE COMMUNITY SCHOOLS IN CHICAGO

In contrast to the neoliberal moment of severe government austerity, there are localized efforts to ensure that historically marginalized communities are able to secure the resources they have been structurally denied. Cases such as Sustainable Community Schools (SCS) in Chicago straddle concerns with built learning environments **(section 7.3.1)** and place-based and community education **(section 7.3.3)**, as they question the necessity for learning to take place within the walls of dedicated, built spaces such as 'schools'. They also reference the wider built environments in which (potential) learners live and attempts to address forms of structural inequality. In Chicago, Illinois, given the realities of the built environment in cities for black and Latinx residents experiencing

'sustainability' in Chicago Public Schools appears in the form of permanent resources secured by a justice-centred teachers union.

poverty and structural racism in the form of disinvestment, food deserts, housing insecurity and dwindling educational resources, 'sustainability' in Chicago Public Schools (CPS) appears in the form of permanent resources secured by a justice-centred teachers union (Chicago Teachers Union). Targeting twenty schools on Chicago's West and South sides, the SCS initiative seeks to infuse historically disenfranchised schools with resources in the form of lower class sizes, support for English language learners, long-term relationships with community organizations, ending harsh discipline policies and access to early learning. Moving from austerity practices where governments remove resources from communities that have historically had the least, SCS has targeted communities and schools that have been historically marginalized to provide them with resources usually provided to schools that are prioritized in the district. Similar to the logics of environmental sustainability, SCS views schools as viable

centres of education if they are replenished with what is needed to create thriving communities inside the school walls, with a long standing commitment to inclusion (e.g. along the lines of race, class, gender (dis) ability and sexual orientation). At the same time, the large emphasis is on 'if'. As funding for SCS was secured as part of a union contract negotiation, late-stage capitalism in the form of budget shortfalls and the current COVID-19 moment unfortunately give school districts and big government the chance to rescind efforts that prioritize marginalized communities. In the broader fight against white supremacy and capitalism – which takes place beyond as much as within school walls – SCS has the opportunity to stand as a model of government accountability rooted in a commitment to address expressed community need **(Chicago Teachers Union, 2018)**.

7

CHAPTER

Built learning spaces can - in conjunction with various rules, norms and teaching practices - have both positive effects on issues beyond academic learning, too - especially around learners' own experiences of power relations, identity and exclusion.

7.3 **.1** **.6**

CONCLUSION

This section has examined evidence about built learning spaces in learning, with a focus on primary to higher education built learning spaces. The section reviewed the intentions of architects and other stakeholders involved in the design of built learning spaces in terms of the effects and outcomes they have sought to engender. It then assessed a range of international literatures exploring the relationship between built learning spaces and learning outcomes, behaviours and student experiences. The evidence on the relationship between built spaces and cognitive learning outcomes remains unclear: certain kinds of (especially flexible) spaces can have benefits for some kinds of learners, but the sheer range of intersecting and complicating factors makes it difficult to be definitive. The evidence about the potentially positive impacts of built spaces on behaviours and senses of well-being is clearer, with, again, flexible environments

leading to a range of positive effects and affects. Built learning spaces can − in conjunction with various rules, norms and teaching practices − have both positive effects on issues beyond academic learning, too − especially around learners' own experiences (and subversion) of power relations, identity and exclusion. Thus, listening to learners' own voices as well as 'measuring' learning or behavioural outcomes is key; this principle is also central to an established body of work highlighting the many benefits (but also challenges) to including learners in the design of built learning spaces. Those benefits can be many, but include a greater sense of 'belonging' with the learning community, greater willingness to learn and the wider benefits of social inclusion and acquiring skills not usually learned in the classroom.

7.3 .2

DIGITAL SPACES

7.3 .2 .1

INTRODUCTION

While it can be assumed that the digital is distinct from the 'physical', this divide is hard to sustain in practice as much of what is discussed as digital learning spaces is an extension of the types of built spaces outlined above – that is the embeddedness of different technologies within built educational spaces **(see WG2-ch6 for a discussion on educational technology)**. Hybrid learning spaces can be understood as (i) physical (with virtual aspects), and (ii) virtual (with physical aspects), with understandings of the latter being contributed to from learning sciences, computer supported collaborative learning and human computer interaction studies **(Ellis and Goodyear, 2016; WG2-ch6)**. While there are numerous reports in the literature of beneficial educational effects associated with a wide

> **Hybrid learning spaces can be understood as (i) physical (with virtual aspects), and (ii) virtual (with physical aspects), with understandings of the latter being contributed to from learning sciences, computer supported collaborative learning and human computer interaction studies.**

variety of computer based teaching systems, especially when used in well-resourced experimental situations, evidence of significant, sustained beneficial effects at scale is mixed **(Pane et al., 2014)**.

This section on digital learning spaces examines work on the promises of digital technology in education, with the most sustained research being in the areas connected to learning to do, and living together or the behavioural aspects of learning, with limited evidence about the connections between digital learning spaces and cognitive learning outcomes. Alongside these promises has come a range of criticisms that the digital technologies of the past forty years have failed to deliver improved education **(Selwyn et al., 2018)**. To examine the ways in which different positions on digital education have implications for what types of learning spaces are conceived and introduced, this section is based on what Ash, Kitchin and Leszczynski **(2018)** outline as 'geographies produced by the digital' which indicate that 'the digital is mediating and augmenting the production

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... critical studies of technology that start to examine not only the pedagogical and curriculum, or practice aspects of these learning spaces but also the politico-economic geographies of learning spaces.

of space and transforming spatial relations' **(Ash, Kitchin and Leszczynski, 2018, p. 29)**. This includes a focus on the unevenness of access to technology and notions of a 'digital divide', that can be about divisions in physical aspects like urban areas and nations, and divisions between and within social categories like race, class, gender and so forth **(Ash, Kitchin and Leszczynski, 2018; McLean, Maalsen and Prebble, 2019)**. Geographies produced by the digital can also encompass infrastructure and software studies, and critical studies of technology that start to examine not only the pedagogical and curriculum, or practice aspects of these learning spaces but also the politico-economic geographies of learning spaces (e.g. forms of privatized data driven learning spaces **(Williamson, 2018)**.

Focusing on geographies of the digital allows us to look at the ways in which technologies are creating new types of learning spaces, including those that we might see as topological – in which students, teachers, schools, universities, lecturers and so

forth – are connected via new networks of infrastructure and the introduction of technologies like virtual reality. These new spaces lead us to questions about what sort of learning, teaching and assessment is being created in these spaces. What is outlined below also speaks to both the ways digital technologies may hasten an end to the traditional classroom, understood as an historically relatively stable walled enclosure, while also extending the possibilities of such classrooms **(Benade, 2017)**.

| 7.3 | .2 | .2 |

DIGITAL TECHNOLOGIES IN FORMAL SETTINGS

This section outlines the extensive research on computer based digital tools in primary, secondary and higher education classrooms. This has been the primary body of work that has connected technology, teaching and learning. This section highlights that while this has been an area of much focus, particularly in higher education, with significant comparative and large-scale

research evidence of how digital learning spaces reshape teaching and learning, there is little substantive research that identifies links between digital technologies and educational achievement. These digital technologies produce material spaces and create new connections between digital and physical spaces.

The use of digital tools is becoming increasingly widespread and heterogeneous. This reflects a conjunction of two trends. Firstly, there has been a strengthening of pedagogical approaches that favour active and collaborative learning, cognitive apprenticeship, guided exploration, learning through participation in valued (knowledge) practices, and experiences that foster learner autonomy **(Lave and Wenger, 1991; Bereiter, 2002; Sawyer, 2014; Lave, 2019)**. Secondly, personal computers and mobile devices have become much more affordable and widely owned – to

In broad terms, tools can be used productively – to create something – or epistemically – to improve one's learning – or both.

the point where, in the richer countries, students are expected to provide their own internet-connected devices. Any such device provides a multiplicity of software and hence opportunities for learning **(Ellis and Goodyear, 2019)**.

The diversity of uses to which a tool can be put means that there is little scientific value in trying to quantify the inherent educational benefits of any specific tool. A better approach is to consider the alignment between tool and purpose, and especially to develop strategies that help students make their own well-justified decisions about which tools to use for which kinds of learning (e.g. cognitive, behavioural). In broad terms, tools can be used productively – to create something – or epistemically – to improve one's learning – or both. Research in this area is now providing better insights into (i) how people develop greater fluency in the use of tools, and (ii) methods for designing and managing learning spaces as complex material–digital ecologies or assemblages of tasks, tools and people. This work

includes a focus on new forms of collaboration, innovation and insights into the incorporation of technology into the physical design of learning spaces **(Verillon and Rabardel, 1995; Säljo, 1999; Moen, Mørch and Paavola, 2012; Dovey and Fisher, 2014; Damsa and Jornet, 2016; Markauskaite and Goodyear, 2017)**.

Contemporary technologies – like social media, smartphones and digital gaming – emphasize learners as active co-producers of knowledge **(Kafai and Burke, 2016; Goodyear and Armour, 2019a)**. Research on these digital technologies in schools has mainly focused on the process of implementation, explaining how, why and for whom digital technologies are effective in given contexts **(Galvin and Greenhow, 2020; Greenhow et al., 2020)**. However, too much emphasis has been on the technology itself **(Greenhow et al., 2020)**, with few studies measuring the impact of contemporary media on student learning outcomes **(Greenhow and Askari, 2017)**, how engagement and learning may vary across diverse and potentially vulnerable groups

(Galvin and Greenhow, 2020), and/or how classroom practices in schools can enrich and relate to young people's informal learning outside of school (Goodyear and Armour, 2019b; Rutledge, Dennen and Bagdy, 2020). One notable exception is the work on the links between behavioural learning and student engagement in the area of what are called 'active learning classrooms'. Using quasi-experiments, Byers and Imms have found what they claim is a causal relationship between: 1) the use of next generation learning spaces with a polycentric design; and, 2) improvements in students' perceptions of the effectiveness of educational technologies, student collaboration, interactivity, collaboration, and preference for the space (Byers and Imms, 2014; Byers, Immsand Hartnell-Young, 2014; Byers, Hartnell-Young and Imms, 2016; Imms and Byers, 2017). Nonetheless, additional research is needed to draw generalizations and to better understand how these contemporary digital media are used in classrooms and in ways that optimize engagement and learning.

There is a body of research that looks at the way digital technologies connect to new forms of learning to live together, superficially work on socioemotional and behavioural aspects of learning. Research exploring participatory cultures (Jenkins et al., 2007; Halverson et al., 2018) and/or the affordance of digital media (Greenhow and Lewin, 2016) helps to explain how digital technologies can create new types of collaborative learning spaces (Halverson and Shaprio, 2013). A participatory culture can be explained as 'a culture with relatively low barriers to artistic expression and civic engagement, strong support for creating and sharing one's creations, and some type of informal mentorship whereby what is known by the most experienced is passed along to novices' (Jenkins et al., 2007, p. 3). Evidence highlights how new technologies create spaces for learning through engendering cultures of play, practice and social interaction (compare Greenhow and Lewin, 2016; Kafai and Burke, 2016; Third et al., 2019; Ito et al., 2020). For example, the social

Evidence highlights how new technologies create spaces for learning through engendering cultures of play, practice and social interaction.

> As a relatively nascent area of research, there is, as yet, little evidence of the connection between smart classrooms and outcomes.

networking affordances of social media, while carrying with them negative effects around bullying and discrimination **(Waters, Russell and Hensley, 2020)**, can enable new forms of inquiry, communication, collaboration and identity work in classrooms, while impacting positively on cognitive, social and emotional outcomes **(Greenhow and Lewin, 2016; Krukta and Carpenter, 2016; Greenhow and Askari, 2017)**. Smartphones and mobile apps afford new pathways for learners to assemble knowledge from diverse sources and in varied formats, rather than a single-source content creator **(Halverson and Shapiro, 2013; Gardner and Davis, 2016; Goodyear and Amour, 2019b)**. Furthermore, commercial and educative digital gaming use in classrooms also provide examples of how game design environments develop different types of spaces to develop expertise, through opportunities for expressions and collaborative problem solving, authentic assessment, automatic feedback, programming skills, creative design, role play and situated decision making **(Kafai and Burke, 2016; Kangas, Koskinen and Krokfors, 2017; Hussein et al., 2019)**.

7.3 **.2** **.3**

HYBRID CLASSROOMS: 'SMART CLASSROOMS', VIRTUAL ENVIRONMENTS AND EMERGING TECHNOLOGIES

This section focuses on 'smart classrooms' in an emerging area of research on technology and learning in 'hybrid' classrooms, cutting across primary, secondary and higher education. It focuses on technologies such as the increased application of artificial intelligence (AI) in the classroom. While AI has long been part of hybrid classrooms, such as Intelligent Tutoring Systems, new forms of AI are now being used, such as facial recognition technologies that aim to not only recognize student faces but also identify and propose learning interventions **(McStay, 2019)**. As a relatively nascent area of research, there is, as yet, little evidence of the connection between smart classrooms and outcomes. However, there is a growing body of both quantitative and qualitative research on the experiences of learners and teachers in these classrooms.

The vision of a smart classroom is 'instrumenting the physical learning space with rich and interactive technologies' **(Tissenbaum and Slotta, 2019, p. 424)**. Smart classrooms are 'technology-rich … equipped with wireless communication, personal digital devices, sensors, as well as virtual learning platforms' **(Li, Kong and Chen, 2015, p. 46)**. This creates a hybrid physical/digital space for learning and teaching where data captured in the physical learning environment and in digital spaces support a 'rich and interactive' smart learning environment.

Smart classrooms are conceptualized as having a range of new digital technologies that capture learning and teaching data through digital devices, sensors, through online platforms and within virtual environments. These are typically understood as part of the Internet of Things (IoT). This also extends to Internet of the Body, which involves wearable devices such as smartwatches and fitness trackers, and classroombased sensors such as video cameras, which automatically collect biometric data for analysis and feedback **(Royakkers et al., 2018)**. Ideally, a rich and interactive smart classroom aims to support learner and teacher activities and decision-making. Some expected uses would be providing teachers with information on the relationship between pedagogical approaches and immediate and long-term student social behaviour; engagement in learning and academic outcomes; and even the relationship between these and environmental factors such as the temperature control of classrooms **(Liu, Huang and Wosinksi, 2017)**.

There is a considerable amount of research in the areas related to smart classrooms. For example, intelligent tutoring systems are widely studied in the field of AI. In particular, how these can be used and expanded in learning contexts to support teacher decisionmaking, in real-time **(e.g. Holstein, McLaren and Aleven, 2017)**. Intelligent tutors are adaptive technologies designed to be responsive to learners and their changing needs, as they progress through a learning task. Questions need to be asked about how these

> Ideally, a rich and interactive smart classroom aims to support learner and teacher activities and decision-making.

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... while local based initiatives have been successful in ameliorating inequitable access to technology for learning, there is little evidence of large-scale systemic success.

are embedded in the learning, rather than replicating traditional teaching approaches. Can these be used in ways that are more immersive, such as pedagogical agents and non-playing characters in serious games, and in ways that take advantage of new learning spaces and places?

7.3 .2 .4

DIGITAL DIVIDES, INEQUALITY, AND UNEVEN ACCESS TO TECHNOLOGIES IN EDUCATION

This section primarily deals with the issue of digital access and inequality, or what is commonly called the 'digital divide' **(Selwyn, 2004)** that connects learning to a range of factors including geography, such as remoteness. The section outlines that the comparative evidence in this area, often undertaken through survey research, has shown that there is significant inequality in technological access. The section also includes evidence that while local based initiatives have been successful in ameliorating inequitable access to technology for learning, there is little evidence

of large-scale systemic success. The section includes a case study of the digital divide in Latin America.

Any instance of digital education inevitably bumps up against issues related to 'digital inequality'. This refers to longstanding (and seemingly persistent) 'digital divides' in levels of basic access to devices and connectivity, alongside less obvious 'second order' differences in the quality of digital engagement once an individual is connected, and the outcomes that accrue as a result **(Selwyn, 2004; Helsper, 2020)**. Around the world, levels of digital exclusion are found to be patterned by issues of race, ethnicity, income and multiple intersections therein. Indeed, with around 3.6 billion individuals (47 per cent of the world's population) still lacking access to the internet **(ITU, 2019)**, any notion of digital technology facilitating a global transformation of educational engagement is profoundly misplaced. Moreover, there are sustained within-population disparities around the world in terms of skills to

use technology, levels of media and information literacy, and other competencies required to benefit from digital technology use **(Broadband Commission for Sustainable Development, 2017)**. As such, digital technologies are acknowledged as both exacerbating existing social inequalities and introducing additional layers of disparity to people's ability to engage in (and benefit from) educational opportunities.

Nevertheless, many people remain profoundly optimistic about the capacity of digital learning to address (and overcome) societal inequalities. On one hand, digital technologies are seen as a ready means of increasing people's opportunities to engage in learning regardless of their pre-existing circumstances. Such optimism surrounds current enthusiasm for a shift to home based virtual schooling – with online technologies believed to give students the ability to engage in education on an 'any time, any place, any pace' basis that best fits with their needs. This was certainly the logic at the beginning of the 2010s surrounding the

initial introduction of MOOCs – massive open online courses – that any individual could engage in for little or no cost **(Rohs and Ganz, 2015; Gameel and Wilkins, 2019)**. This is also the logic of many educational interventions in the Global South. Most notably, perhaps, the much-touted 'One Laptop Per Child' initiative in the 2000s distributed millions of robust self-powered netbook computers to children in some of the most deprived regions with a view to supporting self-directed learning **(Ames, 2019)**. Current initiatives in South Asia and sub-Saharan Africa are continuing this logic – utilizing basic digital technologies such as mobile phones alongside emerging AI technologies to create access pathways to schooling **(Gallagher, 2019)**.

This raises a key tension with regards to the continued application of digital technologies for inclusion and empowerment in education. While these interventions often result in some initial local success, they are usually found to ultimately fail to disrupt or reverse long standing inequalities and disparities in

<div style="background:yellow">Around the world, levels of digital exclusion are found to be patterned by issues of race, ethnicity, income and multiple intersections therein.</div>

Although the digital divide is another way to set up borders between wealthy and poor neighbourhoods, there are initiatives that challenge those barriers...

educational participation. At best these interventions are seen to advantage those who were already advantaged **(Tewathia, Kamath and Ilavarasan, 2020)**. In short, those who benefit most from digital education are those who are already well-educated, well-resourced and without constraining life circumstances – what Tressie McMillan Cottom **(2017)** terms 'the roaming autodidacts'. While digital learning might increase the educational participation of these already privileged classes, it does not usually result in a widening of educational participation to others who were previously not engaged.

This case study focuses on Latin America to link non-formal learning with the promotion of social activism to prevent digital divides. According to DaSilva and Ferreira **(2016, p. 8, contributor translation)**, informal learning in reference to social media and digital learning is '… the process by which people acquire knowledge, skills, and attitudes through everyday experience and exposure to the environment in which they live'. There are studies exploring this kind of learning in terms of control and responsibilization of youth **(Kwon, 2013)** in addition to the tradition of positive youth development **(Kirshner, 2015)**, with both approaches focusing on questions of human development, social integration and possible pathways into employment.

In the community of Abasolo in Chiapas, Mexico, in July 2016, some educators from Escuelas Normales (teacher training

schools) created the collective project Ik ta K'op, which in the indigenous language Tseltal means 'word in the wind'. The initial goal of the project was to share information on the social movement promoted by The National Coordination of Education Workers (CNTE) of 2013 in Mexico. The ultimate result was that, thanks to Ik ta K'op, the community gained internet access and began using common communication platforms, such as WhatsApp, to share information. The main informal learning from this virtual project was building the meaning of 'community internet', 'right of autonomy' and 'internet governance' in that indigenous community **(Lay, 2018)**. Although the digital divide is another way to set up borders between wealthy and poor neighbourhoods, there are initiatives that challenge those barriers, for instance, a free access wireless network was successfully deployed in Ciudad Bolívar in Bogotá, Colombia, after the community worked with non-profit and public organizations **(Pedraza, Cepeda and Ballesteros, 2013)**.

Another important consideration is how the virtual and informal production of learning has an ethnic character, such as the case of learning mathematics in Huánuco, Perú **(Ramón and Vilchez, 2019)** or the development of apps to learn indigenous languages in Mexico **(Le Mur, 2018)**.

The latest, largely unforeseen, crisis caused by the COVID-19 pandemic has ignited a discussion about the changing meaning of space and co-presence in education…

7.3 .2 .5

DATAFICATION, PLATFORMS, AND THE CREATION OF DIGITAL EDUCATION SPACES

This section focuses on the ways in which our understanding of what is a 'learning space' has evolved in response to changed economic and technological conditions, chiefly the explosive growth of pervasive internet platforms and related developments driven by the 'big-tech' sector (e.g. automation and

> ... data footprints not only include learning performance indicators (e.g. tests), but also, to a growing extent, sociodemographic and behaviour data about technology usage.

AI). Evidence of these changing developments has been primarily based on qualitative studies of the experiences of system leaders, teachers and students, and the ways in which the measurement of learning has changed through these developments. There is little evidence of whether these developments are connected to rises and falls in learning outcomes.

The latest, largely unforeseen, crisis caused by the COVID-19 pandemic has ignited a discussion about the changing meaning of space and co-presence in education, with all the opportunities and problems associated with a sudden, hasty 'pivot' to online delivery. What kinds of spaces are therefore created when digital technology becomes, in its various forms, part of the educational milieu? There are two parts to this: (1) datafication; and (2) platforms.

Datafication describes the increasing use of digital data in education, which has meant increases in data volume, variety, concentration and speed that

emerged along with the ongoing expansion of digital learning and education management technologies **(Lawn, 2013; Williamson, 2017; Landri, 2018; Jarke and Breiter, 2019)**. The far-reaching promises of datafication include the capacity to better cater for individual student needs, provide better and faster feedback, optimize classroom management, and reduce workload, as well as monitor learning paths and intervene early enough (for instance, through applying predictive measures) **(Williamson, 2017)**. Students and teachers using such technologies continuously leave (digital) data footprints, which are used for various kinds of data analytics before being fed back into instructional, organizational or governmental decision making. Such data footprints not only include learning performance indicators (e.g. tests), but also, to a growing extent, sociodemographic and behaviour data about technology usage. These technologies have become central to an overlap between new forms of student surveillance and specific forms of behavioural learning **(Manolev,**

Alongside datafication has emerged the growing role of digital platforms in the coordination, governance and surveillance of social life, including education.

Sullivan and Slee, 2019).

Indeed, as digital and automated data increasingly become integral features of educational governance and practice, evidence shows they deeply affect teaching and learning spaces as well as the organization, management and supervision of schools (e.g. Jarke and Breiter, 2019). In doing so, they also show tremendous effects on the (transformation of) subjectivities of teachers and (young) children, which poses new challenges, for example, for professional autonomy and children's rights (e.g. Bradbury, 2019). These challenges are augmented where datafication apparently comes with powerful feedback loop effects – that is, data frequently results in a need for more or better data, more standards, and more focus on (good) data production (Thompson and Sellar, 2018). Ironically, however, even though there is more data than ever before on what happens in schools and classrooms, we still seem to know little or even less about how to improve education outcomes. For example, in countries that have been forerunners in the

datafication of schooling scores in international assessments such as PISA are declining (Hartong et al., forthcoming).

Alongside datafication has emerged the growing role of digital platforms in the coordination, governance and surveillance of social life, including education (Fuchs, 2010; Bucher, 2012; Kelkar, 2017; Van Dijck, Poell and De Waal, 2018; Williamson, 2019). Educational platforms configure digitally produced spaces where key educational processes (teaching, learning and administration) are affected in three interrelated ways:

1. platforms are proprietary and controlled virtual environments where multiple educational actors (e.g. teachers and students) and processes can be digitized, datafied and standardized;

2. through digitization and datafication platforms apportion and individualize educational support and guidance; and

3. through standardization and the development of flexible protocols and infrastructures, platforms

Some studies report positive learning outcomes within educational platforms compared to traditional environments, but these outcomes do not transfer across contexts.

create openings through which third parties (e.g. external, often for-profit, providers of educational services and products) can enter the virtual educational space as add-ons, integrations and extensions.

At the risk of oversimplification, academic research on the emerging platforms in education tends to take one of two positions: one broadly supportive and optimistic and, while involving critique, generally focuses on these contributing to improved cognitive learning outcomes; the other more critical, circumspect and sociological in scope.

The first position relies on data intensive methods and computational approaches and argues that platforms create network effects where people can draw simultaneously on the wisdom of crowds and the personalized assistance enabled by real-time and precise algorithms. This research generally goes by the name learning analytics (LA) and is associated with 'the measurement, collection, analysis and reporting of data about learners and their contexts, for

purposes of understanding and optimizing learning and the environments in which it occurs' **(Long et al., 2011)**. The main aim of LA is the collection of multiple forms of data from a variety of learning platforms and apps, in order to diagnose and predict dimensions of educational performance, and ultimately produce 'actionable insights' of immediate and demonstrable instructional effectiveness **(Clow, 2013; Siemens, 2013)**. Other popular trends include using LA to identify variables and behaviours that promote student success and address the need for quality assurance of educational services **(Lester et al., 2017)**. The evidence supporting these claims is, however, mixed. Some studies report positive learning outcomes within educational platforms compared to traditional environments, but these outcomes do not transfer across contexts **(Winne, 2017; Kizilcec et al., 2020)**. Similarly, experimental research on automation in platforms has found that automated teaching methods have moderate positive impacts, but are only as effective

> **... the main pedagogic feature of platformized spaces is their 'operational bias', which prioritizes seeking to act preemptively, thus removing the need for pedagogic agency.**

as, and often less effective than, human teachers **(Ma et al., 2014; Steenbergen-Hu and Cooper, 2014)**.

The second position draws attention to various forms of reductionism occurring within educational platforms, as a result of logics of prediction and automation **(Perrotta and Selwyn, 2019)**, as well as the growing interface between surveillance, governance and datafication in education policy **(Gulson and Sellar, 2019)**. In this more critical camp, the main pedagogic feature of platformized spaces is their 'operational bias' **(Andrejevic, 2020, p. 95)**, which prioritizes seeking to act preemptively, thus removing the need for pedagogic agency **(Knox, Williamson and Bayne, 2020)**. Notable studies in this camp use data analysis to warn against an overreliance on large datasets, collected through digital learning platforms such as MOOCs, suggesting that platforms do not ameliorate familiar challenges in education: self-selected participation and fragmented, socially stratified patterns of engagement **(Gillani and Eynon, 2014; Rohs and Ganz, 2015)**. In other

words, Big Data does not mean good data, and platforms can be just as problematic as 'traditional' learning spaces.

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CONCLUSION

This section has highlighted that there is substantial evidence for the connection between the following areas of technology and learning spaces: (1) the experiential aspects of teaching and learning including the use of emerging technologies; (2) the impact of technology and technology companies, on how learning is administered and governed; and (3) the enduring inequality of technological access. There is far less evidence on the connections between digital spaces and learning outcomes. The COVID-19 pandemic means that the digital spaces of learning have been widely distributed (away from the buildings of schools to homes) and highly differentiated (with implications for learning outcomes, not just between but within countries) **(Reimers, 2022)**. There remains the need for critical research on the learning effects of

the use of education technology during the pandemic **(Williamson, Enyon and Potter, 2020)**.

7.3 .3

NATURAL SPACES

7.3 .3 .1

INTRODUCTION

This second main section of the chapter's findings recognizes that learning experiences are often designed to occur in, or in relation to, the natural or non-built environment, and that all learning is necessarily situated on and in relation to land. We highlight evidence on how considerations of land are embedded within all education (implicitly and/or explicitly), as well as how land and natural spaces can be engaged more intentionally as part of experiences to learning to know, to do, to be and to live together (or learning 'about, in and/or for' nature). The section will assess the evidence relating to the roles of natural spaces in trajectories of outdoor and environmental education, community and place based education approaches, interspecies learning and education, and indigenous approaches to land and environment in learning and education. Running through these bodies of literature are varying views of whether humans and human-made objects, including built environments, should be considered separate from, or also as part of, the natural world. 'Nature' is understood neither as an objective category or a universal experience; the concept of 'naturalness' needs decoupling from individual understandings of the natural world and the intricacies of specific places in which learning might take place.

7.3 .3 .2

OUTDOOR SPACES AND LEARNING

Various forms of education undertaken 'outdoors,' or in other words, beyond the built environment, are identified in the research literature as a means

Proponents of
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to support people's personal and social development through the building of relationships with self, others and the environment **(e.g. Wattchow and Brown, 2011; Fiennes et al., 2015; Harris, 2018)**. With a range of historical roots in locations such as the UK and Scandinavia **(e.g. Sandell and Öhman, 2010; Freeman, 2011)**, forms of outdoor education are now popular across many societies and offered by non-profit organizations, sometimes for business or leadership training, and also as a means of learning the curricula of formal education. Proponents of outdoor educational approaches reference them as effective interventions for a range of outcomes such as increased confidence, positive affect and communication skills, and developing concern for others and the environment, including for all ages in a range of settings. Outdoor learning is also noted for its ability to be adapted to support a range of curriculum subjects at the primary to higher education levels of formal education. Indeed, outdoor and environmental education programmes have undergone significant

diversification and expansion in recent decades to reach this variety of aims, through a growing call for education that is cross-curricular, locally relevant and emphasizes student responsibility and personal growth **(Beames and Ross, 2010)**. As Gray **(2018a, p. 146)** offers, outdoor learning is not new, 'just newly important', providing a 'potent vehicle for alternative learning' – often premised on experiential learning **(Nicol, 2014)** and making a shift away from transmissive learning approaches.

Whilst challenging to quantify, there is evidence that outdoor education, when planned and well taught, does lead to positive effects **(Hattie et al.,1997; Rickinson et al., 2004; Fiennes et al. ,2015; Ardoin and Bowers, 2020)**. For example, the embeddedness of outdoor learning in Scotland's national Curriculum for Excellence **(Learning and Teaching Scotland, 2010)**, and links to the national curriculum in England and Wales **(DfES, 2006; Ofsted, 2008; DfE, 2018)** demonstrate its perceived ability to contribute to a broad and balanced curriculum that promotes spiritual, moral,

... cultural differences can become a defining pivot in learner's corporeal experiences and associated (negative) interpretations of outdoor learning environments.

cultural, mental and physical development **(DfE, 2014; WG3-ch5)**. It also provides a fundamentally different space from that of the classroom affording learners the opportunity to explore different behaviours and interactions **(Kraftl, 2013; Harris, 2018)**. In terms of contributing to the four pillars of education, 'outdoor learning' typically aligns most strongly with learning to be and learning to do; developing broader 'essential skills' **(Angus et al., 2020)**, such as teamwork and communication that support the use of specialist knowledge and technical skills, and focusing on personal growth and environmental learning, for example, through an emphasis on decision making and social responsibility.

Research demonstrates that in Global North settings, experiences of outdoor learning do not lead to universally positive experiences. The most obvious (but perhaps perceptively diminishing barrier) is the masculinized Outward Bound model that dominates classic outdoor learning rhetoric **(McKenzie, 2003; Gray, 2018b; Riley, 2019)**. Mycock **(2018)** points

to the exclusionary processes that emerge through material engagements with outdoor learning environments and the politics of nature and natural materials, which may be highly gendered. She observes how 'mud governs individuals and their experiences' **(p. 455)** in the context of forest school and school garden spaces, acting to reinstate gendered and class based identities and performances, and limit children's 'muddy encounters'. Other research has suggested that cultural differences can become a defining pivot in learners' corporeal experiences and associated (negative) interpretations of outdoor learning environments **(Friedel, 2011; Hickman Dunne, 2019)**. Attention has also been drawn to the role of (dis)ability – both physical and intellectual – in perceptions of, and reality of access to, particular, nature based learning environments **(von Benzon, 2011, 2018; Hickman Dunne, forthcoming)**. These observations point to some deficits in understandings of the contribution of outdoor and environmental learning

to learners' holistic education. Firstly, for whom is it an effective educational intervention and why, and under what circumstances might it be less effective? Secondly, how applicable is this model of learning to other cultural and geographical contexts, and do we understand the diversity of outdoor learning activity that is taking place across the globe? Natural spaces can be enablers for the pillars of learning and their associated educational outcomes. However, there can be a blindness to the exclusive qualities of nature and outdoor environments, particularly when framed from Western perspectives on outdoor learning.

The promotion of alternative outdoor learning approaches, such as slow adventure **(Varley and Semple, 2015)**, and the embedding learning in place through elements of ecopedagogy **(Kahn, 2010; Payne, 2014; Dunkley and Smith, 2018)**, go some way to addressing some of these deficits. There is no doubt that outdoor education practice has developed to reflect the wider diversity of people who now access it. However, further work that

pushes empirical understandings of people's socially mediated engagements with outdoor education settings is important, to understand the potential of nature to act as a more inclusive and critical learning space.

| **7.3** | **.3** | **.3** |

COMMUNITY AND PLACE BASED LEARNING

The research literature documents diverse trajectories of approaches to community and place based education, most with intended critical and/or environmental learning outcomes. Also taking place on land, and in − or in relation to − non-built or outdoor spaces, approaches describing themselves as 'community based' or 'place based' typically vary from those using the terms 'outdoor learning' in that they are more likely to prioritize social issues and learning (and with environmental learning in much place-based education) **(WG3-ch5)**.

One influential body of work on community based education builds on the work of Brazilian

Engaging adult learners in community-based education to overcome their conditions of oppression through the co-creation of knowledge, this approach has a broad legacy.

> *... focus on the communities most vulnerable to degradation as a result of social and environmental conditions, such as the indigenous, peasants, traditional fisher people and slum dwellers, and have inspired promising research strands.*

educator and philosopher Paul Freire in critical pedagogy. Engaging adult learners in community based education to overcome their conditions of oppression through the co-creation of knowledge **(Freire, 1970)**, this approach has a broad legacy. In Latin America, Freire's legacy strongly influences critical environmental education today, with scholars often highlighting his concept of praxis and the dialectics between 'denouncing the dehumanizing situation and announcing its overcoming' **(Freire, 2000, p. 37)**. Such educational approaches focus on the communities most vulnerable to degradation as a result of social and environmental conditions, such as the indigenous, peasants, traditional fisher people and slum dwellers, and have inspired promising research strands. For example, the 'education in public environmental management' project, based on a critical pedagogy framework, aims at promoting participatory democracy in the management of territories; and 'community based environmental education' and has

also been inspired by decolonial theories and political ecology **(Quintas, 2007; Almeida and Loureiro, 2015; Magalhaes and Loureiro, 2016; Souza and Loureiro, 2018; Vitor, Goncalves and Sanchez, 2019; Melo and Barzano, 2020; Oliveira, et al., 2020; Pelacani et al., 2020; Stortti, Espinosa and Garcia, 2020)**. A review of critical environmental education research in Latin America **(Sanchez, Pelacani and Accioly, 2020)** suggests that the urgency of a fairer distribution of wealth and income and the workers' rights movement has mobilized grassroot approaches to critical community based education. This trajectory of critical work has also informed approaches to ecopedagogy and other perspectives on critical environmental education **(e.g. Kahn, 2010: Misiaszek and Torres, 2019)**.

Using a community-as-pedagogy framework **(Freire, 1970)**, a study of a community based education programme in a Latin American rural high school context investigated how community connections strengthened students' perceptions of social relationships and environmental leadership **(Selby et al., 2020)**. The

results showed an increase in students' knowledge of the local environment and community environmental issues. It was an endeavour to draw attention to, and encourage engagement in, complex socioenvironmental issues and to help transform 'youths' ability to envision, enact, and expand upon community-derived conceptions of "environmental leadership"' **(p.2)**.

A second related trajectory of community and place based learning emphasized in the research literature is the 'environmental justice' movement and its impacts on education. In the 1980s, environmental justice emerged in the USA as a social movement that linked social justice and environmentalism. Distinct from conservationist forms of environmentalism, environmental justice framed notions of the environment broadly and recognized that all environmental spaces, natural or built, are tied to power relations **(Bullard, 1990; Teelucksingh and Masuda, 2014)**. Structural inequities and differential access to power results in affluent white communities being better able to protect their environments from undesirable land uses **(Pulido, 2000)**. In contrast, those who are marginalized poor, racialized and indigenous, in both more developed countries and less developed countries, bear the burden of environmental risks, such as pollution, climate change and exploitation of their land and natural resources. The spatial dimensions of environmental injustice include both the risk distributions that concentrate in areas of deprivation **(Bullard, 1990)** and also the terms of risk causation, as found in the sociospatial politics that surround truth claims made by competing stakeholders involved in environmental decision making **(Waldron, 2018)**.

Environmental justice is posed in the literature as uniquely tied to both formal and informal learning spaces and the need for integrated visions of learning **(Haluza-DeLay, 2014)**. Formal education settings are key sites to conduct evidence based research that validates the everyday experiential knowledge of grassroots environmental justice

... those who are marginalized poor, racialized and indigenous, in both more developed countries and less developed countries, bear the burden of environmental risks ...

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Theoretically based on theories of social capital and relational power, Warren calls for a new approach to urban education reform that is linked to social changes in America's cities.

actors. Many of these actors are women and indigenous people who become activists because of the risks they bear. Schools can also play a role to inform children of their social justice and citizenship rights to access healthy environmental spaces, especially for children who live in communities that suffer from environmental injustices **(Peloso, 2007)**. In turn, grassroots environmental organizations, which position marginalized communities as active agents of change, provide informal learning that empowers and fosters environmental resilience.

A wide range of initiatives has also recently emerged across the USA in order to promote connections between community based organizations and schools. Warren **(2005)** states that such community initiatives can contribute to school improvement through improving the social context of education, fostering parental and community participation in education, transforming the culture of schools by holding school officials accountable for educational gains, and building a

political constituency for public education to support the delivery of greater resources to schools. Warren links the success of urban school reform to the revitalization of communities around the schools through developing collaboration between public schools and community based organizations. In order to do this, Warren identifies a typology of three approaches and exemplar models for each: the service model (community schools), the development model (community sponsorship of new schools), and the organizing model (school–community organizing). Despite the differences, these three models appear to have a number of features in common and all seek to build stronger and more collaborative connections between and among parents, educators and community members. Based on theories of social capital and relational power, Warren calls for a new approach to urban education reform that is linked to social changes in America's cities. The review concludes that community based education can build social capital

> Place based education has emerged as an approach, harnessing locally distinctive contexts into teaching and learning, including its geography, ecology, politics and sociology.

among educators, parents and community, which can expand the capacities of schools in a way that it calls 'a new view of urban education reform'.

A third central body of literature on place based and place-responsive education has developed more recently. This research extends prior work on community based education to account for 'place' in educational provision, including a focus on communities as well as the land and natural settings within which they are embedded. Place based education has emerged as an approach, harnessing locally distinctive contexts into teaching and learning, including its geography, ecology, politics and sociology **(Woodhouse and Knapp, 2000)**. For the last several decades, the heterogeneous movement broadly termed here, 'place based education,' has sought to facilitate learning in local areas through providing students with opportunities to encounter local people, local issues and to experience phenomena in a 'real world' setting beyond the classroom. Other identifiable

sub-fields of the loosely linked movement are curricular provisions for place-responsive learning, area studies, urban education and other forms of place related formal and non-formal education.

In the scholarly research literature, place initially emerged as a key context for 'place based' pedagogies of various kinds **(Gruenewald, 2003; Sobel, 2004; Skamp, 2009)**. Linking his work to that of Dewey, Smith **(2002)** suggests place-based education grounds learning in the local or the particular place of students' lived experiences. Early perspectives extended critical pedagogy to take account of the role of the setting or eco-social context of education. Gruenewald (later Greenwood) **(2003)** theorized 'critical place based' and 'place-conscious education' and later argued the need for an examination of places to reveal 'the often contestable nature of the dominant beliefs and motives' **(Greenwood, 2013, p. 97)** that shape our perspectives of places. A number of authors **(Ingold, 2000, 2011; Somerville, 2008; Payne and Wattchow, 2009; Wattchow and Brown,**

... in addition to enhancing community-school relationships and students' attitudes toward their schoolwork and their communities, place based education affects student motivation for, and engagement in, learning.

2011; McKenzie and Bieler, 2016) have sought to particularly understand the processes of place based learning. For example, Sellers **(2009)** suggests that curriculum itself needs to be considered as a 'milieu of becoming' wherein assembled entities change as they expand their connections to each other and to other newly encountered entities or beings **(see also WG2-ch8; WG3-ch5)**.

Informed by process philosophies (e.g. Heidegger and Deleuze), a proliferation of writing has used the term 'place-responsiveness' in an effort to sustain and understand how people and places are in ongoing reciprocal relation via learning **(Cameron, 2003)**. Mannion, Fenwick and Lynch **(2013)**, among others, link place-responsiveness with educational endeavour in the term place-responsive pedagogy, which they define as explicitly teaching 'by-means-of-an-environment' with the aim of understanding and improving human–environment relations. It involves educators' own experiences and dispositions to place, learners' dispositions and experiences, and

the ongoing contingent events in the place itself (including the presence and activities of other living things). Other education research has focused on psychological orientations to place and place attachment, and has emphasized various aspects of place that can shape learner identity, including through place based learning **(Chawla, 1992; Ardoin, 2006; Kudryavtsev, Stedman and Krasney, 2012)**. In an evaluation of four place-based education programmes, Powers **(2004)** finds that in addition to enhancing community-school relationships and students' attitudes toward their schoolwork and their communities, place-based education affects student motivation for, and engagement in, learning. A salient emerging theme is that special education students performed better during the place-based learning activities.

School and community gardening also offer the opportunity to centre cultural and biological diversity and interdependence.

BOX 3. SCHOOL BASED GARDEN LEARNING

Teachers, school leaders and communities are responding to increased food insecurity and the need for more outdoor learning spaces by connecting with community gardening and small farming as living classrooms **(Williams and Brown, 2012; DiClaudio, Hughes and Savoca, 2013; Williams and Anderson, 2015)**. Research has found that garden based learning spaces offers unique opportunities for teachers to connect students with important global nutrition issues and local economic alternatives for students learning food growing, preparation and consumption, while also learning about important social justice and sustainability issues **(McKenna and Brodovsky, 2016; Niewolny and D'Adamo-Damery, 2016)**. In many garden-based learning spaces, schools and teachers have the opportunity to situate gardens as learning labs for science learning and closely connect students with skills for addressing food insecurities and centering civic engagement around food politics. School and community gardening also offer the opportunity to centre cultural and biological diversity and interdependence. One example of garden learning can be found in Portland, Oregon at the Learning Gardens Laboratory (LGL). This is a 12-acre garden where university students and community members work with young learners through hands-on and place-based education. The LGL is one of a growing number of garden learning spaces in the city of Portland where the focus of learning includes sustainable gardening and healthy nutrition through permaculture **(Williams and Anderson, 2015)**. Another example is the D-town Farm

Walking pedagogies offer opportunities to circumvent the implicit lessons of institutionalized environments, while also raising opportunities to explore the curricula found in different spaces and places.

where black urban farmers have a Food Warriors programme that engages youth in food systems learning that focuses on a sense of agency through food justice, environmental awareness, diverse agricultural techniques and health food preparation **(DBCFSN, 2019)**. Furthermore, examples of garden learning rooted in land based education and decolonial efforts are centring indigenous ways of knowing as central to students learning **(Tuck, McKenzie and McCoy, 2014; Bang, 2016; Lever, 2020)**. Most important in both garden based learning and food pedagogies, is that learning spaces are sites of learning to recognize multispecies interdependencies and how such systems require critical understanding in order for us not only to survive but thrive together on the planet.

In addition to research on the effects of being in particular places for learning, there is also a literature on the benefits of movement across places, such as the scholarship on walking

pedagogies. Walking is receiving attention for its capacity to enact curricular and public pedagogies, as well as community action, but also because of the critical place engagement that it offers **(McPhie and Clark, 2015; Springgay and Truman, 2019)**. Walking produces opportunities for different forms of socialization and subjectification when compared to sitting in more homogeneous and static environments where students sit at desks in rows, facing one direction. 'Materialities of classrooms do crucial but often unnoticed performative work in enacting gendered power' **(Taylor, 2013, p. 688)**, as well as reinforcing racial, colonial, ableist and class/caste powers. Similarly, ostensibly public spaces, notably urban environments, but also rural spaces, have become increasingly commodified and privatized, further shaping how it is possible to be in these places **(Richardson, 2015)**. Walking pedagogies offer opportunities to circumvent the implicit lessons of institutionalized environments (indoor and outdoor), while also raising opportunities to explore the curricula found in different spaces and places.

Walking pedagogy is, however, not inherently equitable. Walking is a cultural construct and is changeable for different people, in different environments, at/in different times. Some people are more physically able to walk than others (and some may not be able to walk at all). The shape, position, length of stride and speed of your walk can signal privilege or poverty **(Becker, 2016)** −for example, where just walking down a street as a person of colour can be taken as an act of criminal intent in some places **(Cadogan, 2016)**. In contrast, the pastime of walking in the countryside for leisure or well-being is most often undertaken by privileged white people in the Global North due to their conceptions of landscape and the urban, and prevailing ableist and privileged notions of health and access. Walking pedagogues have a responsibility and opportunity to consider what their walking pedagogies allow (and for who), what they might reinforce (and to whose detriment), and what they might disrupt (and for whose empowerment). Walking has been researched as pedagogy in a range of formal-and-non-informal settings, including in outdoor learning **(Beames, Higgins and Nicol, 2012; Gray and Colucci-Gray, 2019)**, decolonial walking pedagogies **(Walsh, 2015)**, walking libraries for women **(Heddon and Myers, 2020)**, non-ableist walking **(Stenning, 2020)**, participatory methods of research **(Snepvangers and Davis, 2019; Borthwick, Marland and Stenning, 2020)**, radical performance **(Smith, 2015)**, and First Nations protest and/or liberation **(Hamilton, 2020)**.

7.3 **.3** **.4**

INTERSPECIES LEARNING

Research that focuses on the relationships among humans and other aspects of the material world embraces not only animate beings but inanimate and inhuman elements **(Ogden, Hall and Tanita, 2013)** in opening up new accountabilities in understanding learning spaces **(Van Dooren, Kirksey and Münster, 2016)**. The human is understood to emerge, or in other words learning takes place, through relations with other agentive beings **(Rautio, Tammi**

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... learning takes place, through relations with other agentive beings.

and Hohti, 2020; see also Hohti and Tammi, 2019**).** As Tsing **(2012, p. 141)** contends, 'Human nature is an interspecies relationship'. Thus, growing up is understood to be inherently about co-becoming of humans with other life – animate and inanimate **(Hird, 2009).**

There is nothing particularly new about a focus on relations – on humans as interconnected with nature per se. It is not historically novel, as Bach **(2018)** points out, nor is it new to many Indigenous cultures **(Ellis, 2005; TallBear, 2011).** The newness arises from the current means – technologies and ways of thinking – with which we can learn more about the multispecies webs that enable our existence.

Advances in fields surrounding education proper, such as childhood studies or childhoodnature approaches **(e.g. Horton and Kraftl, 2018; Cutter-MacKenzie-Knowles, Malone and Barrat, 2020; Kraftl, 2020),** as well as environmental education **(e.g. Lloro-Bidart and Bansbach, 2018; Kraftl et al., 2019),** have for some time emphasized attention to connectivity and coexistence

through approaches labelled as (new) materialist **(Snaza et al., 2016),** sociomaterialist **(Fenwick, Edwards and Sawchuck, 2012; McKenzie and Bieler, 2016),** posthumanist **(Snaza et al., 2014)** or multispecies inquiry **(Rautio, Tammi and Hohti, 2020).** Most of these have exemplified a shift of focus both empirically and onto-epistemologically from individuals to relations and multiplicities, from large-scale certainties to micro-scale situatedness and webs of interrelations, exposing, for example, systems of domination at work in curriculum and pedagogy **(Snaza et al., 2016).** Deborah Bird Rose **(2011),** among many environmental philosophers, stresses a shift from atomism to connectivity, and from certainty to uncertainty. Education, however, has been among the slowest of disciplines to attend to these shifts **(e.g. Pedersen, 2010),** and has instead celebrated universal (e.g. ahistorical, apolitical, geographically and spatially indistinct) ideas of learning **(Fenwick, Edwards and Sawchuck, 2012; Snaza et al., 2014).**

Some process-oriented educational research, sometimes described as 'new materialist', or 'post-human', now emphasizes our lived and embodied experience in educational settings **(Kraftl, 2013)**. These researchers actively target the binary of culture/nature and the idea of human stewardship of nature **(Taylor and Pacini-Ketchabaw, 2015; Malone, Truong and Gray 2017)**. Others emphasize the significance of learner embodiment in settings **(Hackett and Somerville 2017)**. Lloro-Bidart **(2017)** considers the role of non-humans, suggesting that other species and the human can be a 'community of knowers'. Post-human or 'more-than-human' approaches, therefore, seek a revision of modern ideas such as 'stewardship' of environments (with its paternalistic associations of mastery and control), challenging learners towards a greater acceptance of the current state of environmental crisis (for example climate change and biodiversity loss), and foreground the importance of alternative ways of knowing (via, for example, indigenous knowledge, embodied and affective knowing, and ethical response-abilities). Pederson **(2011)** and Quinn **(2013)**, clarify that such approaches must decentre the human subject so that we can develop an 'understanding of what it means to learn with and from rather than about nonhuman animals' **(Pederson, 2011, p. 20)**.

In-depth research about child–animal relations highlights human children and other animals as co-becomings **(Van Dooren and Rose, 2012; Hohti and Tammi, 2019)**. It is suggested that human–animal relations can, in general, be conceived as powerful relationships intrinsic in their value to children **(Risley-Curtiss, 2010; Tipper, 2011)**, and reviews of research show that caring for a companion animal may promote respect and compassion for all animals and nature **(Prokop and Tunnicliffe, 2010)** as well as increase general health and well-being **(McCardle etal., 2011)**. Childhood nature or child–animal scholarship shows that a situated learning with (cf. learning about) produces connections and a sense of belonging **(Taylor et al., 2015; Cutter-Mackenzie-Knowles, Malone and**

Some process-oriented educational research, sometimes described as 'new materialist', or 'post-human', now emphasizes our lived and embodied experience in educational settings.

... common worlds pedagogies seek to cultivate pedagogical attention to environmentally damaged places in ways that resist reinforcing the human-centredness on which our current times of environmental precarity were formed.

Barrat, 2020). This kind of research further argues that situated relations and forms of education are performative: they are world-making (Haraway, 2008) and, as such, relevant to education far beyond learning.

As one trajectory of work concerned with these framings, common worlds pedagogies propose alternatives to dominant educational approaches that promote universalized understandings of 'the developing child', instead situating young children within the actual worlds they inherit and inhabit amidst current conditions of global environmental precarity (Taylor, 2013, 2017; Taylor and Pacini-Ketchabaw, 2015; Kraftl, 2020). While recognizing the importance of children's physical, emotional and other aspects of well-being, common worlds pedagogies seek to cultivate pedagogical attention to environmentally damaged places in ways that resist reinforcing the human-centredness on which our current times of environmental precarity were formed. Therefore, rather than re-centering the child, through

everyday pedagogical encounters, common worlds approaches work with pedagogies that notice and respond to children-in-relation with the more-than-human as a conduit for creating more livable worlds for all – where the more-than-human includes materials, other species, land, weather and more.

Examples of this work include studies of children's relations with local impacts of climate change (Rooney, 2019), polluted waters (Nxumalo and Berg, 2020), waste (Hodgins, 2015) and plastics (Kraftl, 2020; Berry, Vintimilla and Pacini-Ketchabaw, forthcoming). Central to an emphasis on children's place relations and the refusal of human-centredness, is a commitment to considering places and their more-than-human inhabitants as storied, vibrant and active participants in children's relational learning, rather than a mere background for children's learning. Common worlds perspectives on place and the collective learning therein are transdisciplinary, drawing from indigenous land pedagogies (Bang et al., 2014; Simpson, 2014),

new materialist perspectives on affective pedagogies **(Blaise and Pacini-Ketchabaw, 2019; Nxumalo and Villanueva, 2019)** and more-than-human geographies of place **(Instone and Taylor, 2015)**, amongst other influences **(Taylor, 2017)**.

Since much of the work of common worlds scholars is situated within settler colonial contexts, engagements with children's place relations also include foregrounding the ways in which childhood pedagogies can disrupt the erasure of Indigenous communities, knowledges and lands **(Nxumalo, Vintimilla and Nelson, 2018; Land et al., 2019; Nxumalo, 2019)**. In addition, common worlds pedagogies attempt to confront the impacts of settler colonialism through attention to fraught relationships and awkward encounters between children and animals such as raccoons **(Pacini-Ketchabaw and Nxumalo, 2015)**, rabbits **(Taylor, 2020)**, bees **(Nxumalo, 2018)** and kangaroos **(Taylor and Pacini-Ketchabaw, 2018)**.

Within a focus on the ethics and politics of children's place relations, recent common worlds work has drawn on black feminist geographies and black speculative storytelling to re-imagine childhood pedagogies as capable of interrupting the absenting and deficit constructions of black children's relationships to so-called natural places **(Nxumalo and Cedillo, 2017)**. Taken together, this literature suggests a need to attend to the ways in which place and space are central to black, indigenous and other intersectionally marginalized people's oppression and liberation

| 7.3 | .3 | .5 |

INDIGENOUS LAND BASED LEARNING

A final area of research that informs current understandings of 'natural spaces' of learning is that of Indigenous land-based approaches to education. Bang et al. **(2014)** have written that 'Land is; therefore, we are', recognizing that within indigenous cosmologies, existence and identities are inseparable from relationships with the land.

> ... engagements with children's place relations also include foregrounding the ways in which childhood pedagogies can disrupt the erasure of Indigenous communities, knowledges and lands.

Formal education systems, a critical component of the machinery of colonization and initially designed to assimilate and enfranchise indigenous peoples, have been a poor substitute for the pedagogy of the land.

When we (indigenous people) speak of the land, we are referring not simply to the piece of ground on which we might stand but also to the water, sky, human and non-human beings, spirits and forces that, in their reciprocal relationships, form and sustain all life. Over indigenous peoples' long history, the land has been our most valuable site of learning and source of knowledge **(Simpson, 2014; Cajete, 2015; Wilson and Laing, 2019)**. This has been disrupted, however, by the colonization, settlement and creation of colonial nation states on our traditional territories – processes that start with and are continuously maintained by the displacement and dispossession of Indigenous peoples from their lands. Settlers' claims to our territories, resource extraction and industrial activities continue to erode our access to the land. Formal education systems, a critical component of the machinery of colonization and initially designed to assimilate and enfranchise indigenous peoples, have been a poor substitute for the pedagogy of the land **(Simpson, 2017)**. Beginning with our children's forced attendance at residential schools in the mid-1800s and persisting today, educational systems in settler colonial countries have been sites of epistemic and ontological violence against indigenous peoples **(Simpson, 2014; Wildcat et al., 2014; Ahenakew, 2016; Hall and Tandon, 2017; Wilson and Laing, 2019)**. Both inside and outside the classroom, our lands, bodies, identities and ways of being and knowing have been regulated, controlled, policed and reconstructed by steadily enforced colonial regulations and norms.

Land-based education is one way that Indigenous peoples continue to resist the violence of colonial systems. As Wildcat et al. **(2014, p. 1)** argue, 'if colonization is fundamentally about dispossessing indigenous people from land, decolonization must involve forms of education that reconnect Indigenous peoples to land and the social relations, knowledges and languages that arise from the land'. Simply moving students from a classroom to the land is not equivalent to 'decolonizing' or 'Indigenizing' education. The change in location must

be accompanied by 'a change of philosophy, a change of curriculum, a change of teaching methodologies, a change of content' **(Wilson and Wilson, 1999, p. 138)**. Rather than the 'self-in-relation' model that prevails in Western culture and has formed the basis of educational practice and policy in mainstream school systems, the framework for land-based education is a model of 'self-as-relationship… rooted in the context of community and place' **(Wilson, 2001, p. 91)**. This sense of self generates a pedagogy that centres on the land and all our relations (those we share the land with; all that forms, animates and sustains human and non-human life; and our collective and individual experience, knowledge and perspectives) as our primary texts and teachers.

Over the last few decades, a growing number of First Nations and other school systems have moved away from classroom based teaching and taken up or returned to land based education. Encouragingly, this has contributed to the revitalization of indigenous traditional teachings,

practices and languages. At the same time, however, many land based programmes draw on, promote or entrench supposedly 'traditional' teachings, ceremonies and practices that, in fact, incorporate colonial dogma, hierarchies, roles and protocols that reflect the influence, internalization and transposition of colonial, Judeo-Christian and Western constructs relating to gender, sexual orientation, race and class **(Denetdale, 2006; Wilson, 2015, 2018; Wilson and Laing, 2019)**. These include, for example, requiring trans or two-spirit people to assume gender roles in ceremonies that conform to the gender assigned to them at birth, imposition of types of clothing, enforcing women to sit a certain way, the professionalization of the role of Elders and the commodification of ceremonies and 'traditional knowledge'. The avenue through which Judeo-Christian and Western culture has corrupted misconstructed 'traditional' teachings, ceremonies and ways of being has been colonial practices, such as church-operated residential schools and

... the framework for land based education is a model of 'self-as-relationship ... rooted in the context of community and place'.

the legally enforced suppression or criminalization of Indigenous spirituality and lifeways. Repetitive experiences of epistemic and ontologic violence have left many of our Elders understandably reluctant, unwilling or unable to pass along teachings and practices from their own families and communities to subsequent generations.

Queering land-based education challenges problematic 'traditional' teachings and practices, Hunt and Holmes **(2015, p. 156)** describe queering as 'a deconstructive practice focused on challenging normative knowledges, identities, behaviours, and spaces thereby unsettling power relations and taken-for-granted assumptions'. In the context of Indigenous land-based education, this deconstructive practice applies to both what we teach (including, for example, challenging prevailing essentialist constructs and understandings relating to gender or sexuality) and how we teach (including, for example, our expectations with respect to where teaching and learning

take place, who our teachers are, or what appropriate power dynamics might be within a group of students and teachers). Queering land-based education also demands our focus on what might best be described as 'reconstructive practices', that is, the radical reclamation and reassertion of Indigenous peoples' cosmologies, of our relationships with the land, and of the knowledge and practices that have nourished and animated these relationships and have enabled and supported our survival, sustainability and well-being. Taking queer theory out of the classroom and into the bush removes it from the abstract context of a text and situates it and us, as teachers and students, in the multitude of relations that constitute the land and ourselves. Together, we place ourselves in what Muñoz **(2009, p. 22)** might call 'a sort of ontologically humble state', recognizing that what we think we know about queerness, about the land and about ourselves as teachers and learners will be continually reshaped by a practice of relational

accountability, reciprocity, radical listening and a readiness to unlearn and learn anew from and with the land and each other.

7.3	.3	.6

CONCLUSION

This section has provided overviews of key areas of research on the role of natural or non-built spaces in learning. This included diverse bodies of work on outdoor and environmental learning, community and place-based learning, interspecies learning and indigenous land based learning. While the framings and research reviewed here are not exhaustive, they provide a broad sense of the types of ways that non-built or more natural environments can shape learning to 'know, do, be, and live together' **(International Commission on Education for the Twenty-first Century, 1996).** These learnings surpass the intended curricula of formal, non formal and informal education programming and also include the unintended or hidden learning taken from the ways we implicitly interact with the places and world around us. In considering education that goes beyond academic learning to challenge and provide new directions to the big issues of our times, such as colonialism, racism, gender-based violence, fascism, climate change denialism, technologism and more, the research reviewed here suggests possible critical directions for more intentional engagement with natural learning spaces in the futures of education.

7.4 [Key messages (implications for education policy and practice)](#)

The wide-ranging evidence reviewed in this chapter suggests a myriad of implications for understanding and designing learning spaces. Core to its contributions, however, is the growing recognition that where education takes place matters for what is learned – whether that be cognitive, socio emotional or behavioural learning – both intentionally, as well as unintentionally, through what is afforded or assumed in various leaning environments.

Core to its contributions, however, is the growing recognition that where education takes place matters for what is learned - whether that be cognitive, socio-emotional or behavioural learning - both intentionally, as well as unintentionally ...

As a corollary, trajectories of research have identified that who has access to different kinds of learning spaces also limits or enables what is able to be learned. Inequities of race, colonization, region, gender, income, ability and other factors shape access to various types of digital, natural and built learning spaces, and thus people's access to learning and their experiences of it.

These core understandings, as well as their nuances, have many implications for education policy and practice. In relation to exploring further the 'best place' for various learning foci and outcomes, this has, to date, been inadequately considered in education policy in primary to higher education settings. Still too often, education is taking place in classrooms that remain unchanged from those envisioned at the beginning of mass schooling. There are miseducative effects if we assume that optimal learning occurs through transmissive modes and stationary bodies, and that all types of learners can equally be engaged through mainly cognitive orientations to education

and learning. Understanding learning as requiring doing and being, as involving social and emotional practices and active capacities, then requires more attention to the built and non-built spaces in which learners interact, move and effect change in living together. The assumption that adding datatification and digital platforms to, or in lieu of, classroom based settings is inherently positive for student engagement and learning also needs to be further problematized. While digital means can, in some cases, provide further access to and modes of learning, the evidence suggests they need to be considered critically to determine the circumstances under which they can indeed be beneficial.

The research indicates the scope for education policy and policy-making to further engage with the growing evidence on the benefits of varied environments for cognitive, as well as socio-emotional and behavioural, learning outcomes. This includes:

- not only considerations such

as accessible and sustainable school design, but also when being outside of school buildings in outdoor, community, place and land based settings can increase the sense of meaning and connection that learners gain from their education and lives;

- a consideration of the benefits of non-formal/ informal learning; in an age of increasing digital connection and yet personal isolation, and associated lowered mental health outcomes for youth and adult learners, it is critical that formal learning go beyond future job training, to enable learners to find belonging and purpose in their present contributions to a complex and at-risk world;

- connecting formal schooling with the research on the importance of experiential and place-based learning.

Practitioners often have an experienced understanding of how to engage learners in learning to know, do, be and live together in ways that are experiential and placebased, to move through and outside of schools and university

classrooms and digital spaces, to enhance engagement and learning. However, without the support of policy, professional development and parental and community education, they also face challenges in trying to diversify and optimize the use of learning spaces to benefit learners.

Overall, further consideration is needed of how both policy and practice can be advanced to more intentionally engage with the effects of learning spaces for a variety of learners.

7.5

Key recommendations (policy recommendations, future research)

We close by highlighting some key recommendations for policy-making and future research.

POLICY RECOMMENDATIONS

Based on our assessment, the following have been identified as areas of need for policy-making that further address learning spaces.

- As outlined above, education policy-makers would benefit from further considering the 'where' of learning in curriculum and pedagogy (policy-making), as otherwise the 'where' can be at cross purposes, rather than supporting and contributing to, the intended 'what' of education.

- There is a need to increase education policy's consideration of informal and non-formal learning contexts. This includes recognizing the need for a broader uptake of non-school based learning for furthering socioemotional and behavioural learning outcomes, as well as increasing cognitive

learning outcomes for a diversity of learners.

- Further consideration is needed of how new technologies and insights in architecture are changing, and can transform the insides of classrooms and schools, their configurations, objects, relationships and other aspects that can optimize or contribute to learning outcomes.

7.5 .2

RECOMMENDATIONS FOR FUTURE RESEARCH

Based on our assessment, the following have been identified as areas of need for future research on learning spaces.

- Longitudinal and comparative work on changes in learning space design and cognitive learning outcomes. This could focus on outcomes associated with sustainable design (and connected to the SDGs) and hybrid spaces, as well as be more sensitive to the diversity of spaces and ways in which people learn around the world.

- Interdisciplinary research on the interconnections of built space, natural spaces and digital spaces.

- Increased research on non-school learning and the relationship of non-school learning to systems.

- Research implications of considering other species and objects as influences on learning.

- Broadened research focus on informing all education with Indigenous and land-based priorities.

- Expanded research on ethical issues of the use of artificial intelligence and smart classrooms, including data collection on students and teachers.

- Research on teacher led implementation of smart classrooms and learning outcomes.

- Displacement, refugee children and associated unique digital education needs.
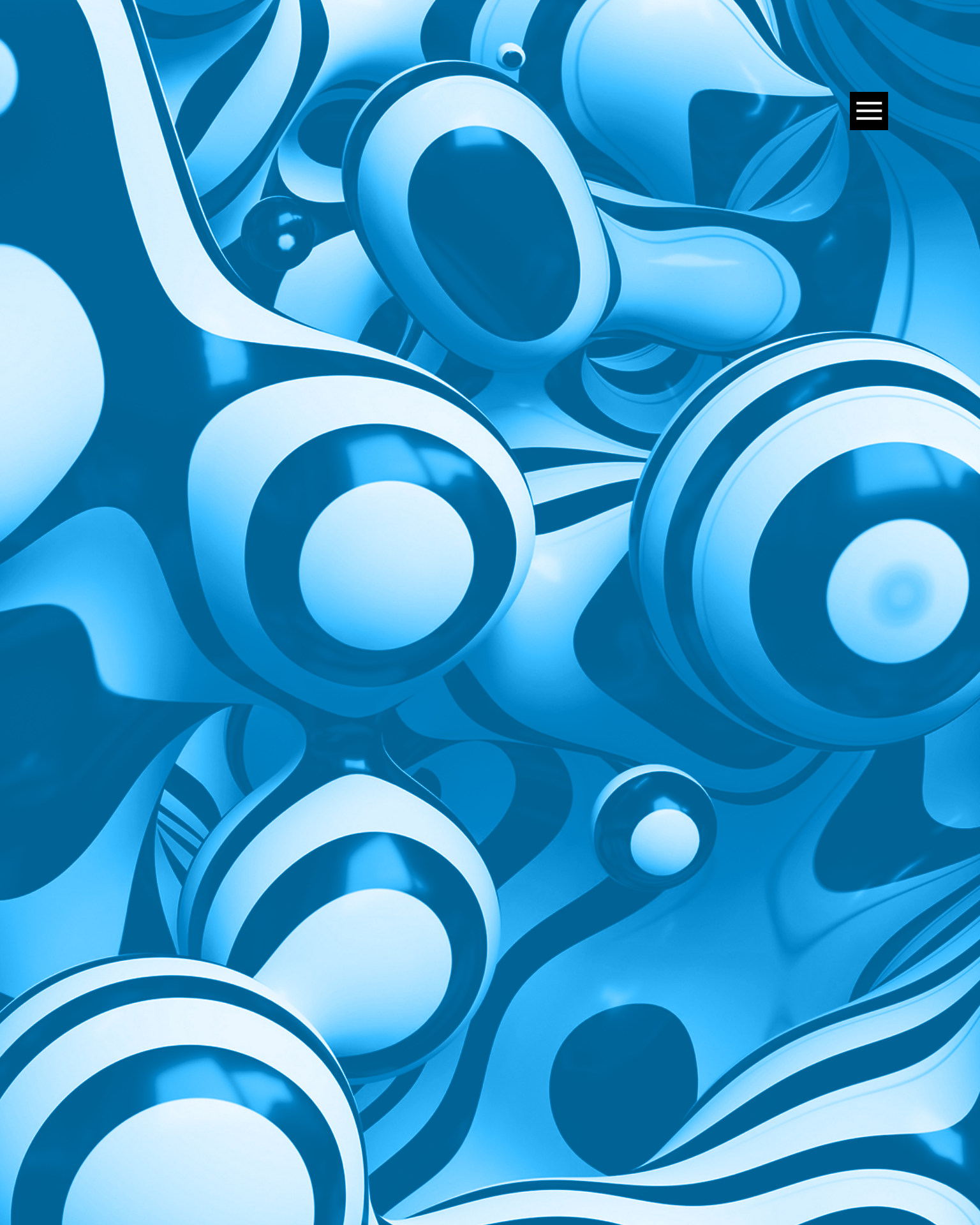
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KEY ACRONYMS

123

3D: Three-Dimensional

ABC

AAC: Augmentative and Alternative Communication

ABI: Acquired Brain Injury

ACC: Anterior Cingulate Cortex

ADHD: Attention Deficit Hyperactivity Disorder

AI: Artificial Intelligence

AIED: Artificial Intelligence in Educational Development

ALE: Activation Likelihood Estimation

ASC: Autism Spectrum Condition

ASD: Autism Spectrum Disorder.

AT: Assistive Technology

BDNF: Brain Derived Neurotrophic Factor

BMI: Body Mass Index

BPEB: Building Performance Evaluation

CA: Canada

CARE: Cultivating Awareness and Resilience in Education

CASEL: Collaborative for Academic, Social, and Emotional Learning

CBTS: Computer Based Tutoring Systems

CCA: Canadian Council for the Arts

CCE: Climate Change Education

CCL: Canadian Council on Learning

CD: Conduct Disorder

CDA: Cognitive Diagnosis Assessment

CNAT: Clasby Neurodiversity Assessment Tool

CPS: Collaborative Problem-Solving

CRPD: Convention on the Rights of Persons with Disabilities.

CSCL: Computer Supported Collaborative Learning

CVT: Control-Value Theory

DEF

DA: Dynamic Assessment

DBCFSN: Detroit Black Community Food Security Network

DESD: Decade of Education for Sustainable Development

DfE: Department for Education

DFID: Department for International Development

DH: Department of Health.

DI: Differentiated Instruction

DNA: Deoxyribonucleic Acid

DSD: Department of Social Development

DSM: Diagnostic and Statistical Manual of Mental Disorders

DSMMD: Diagnostic and Statistical Manual of Mental Disorders

DT: Design Thinking

DTI: Diffusion Tensor Imaging

DWCPD: Department for Women, Children and Persons with Disabilities

EBE: Evidence Based Education

ECCE: Early Childhood Care and Education

ECE: Early Childhood Education

EdTech: Education Technology

EE: Environmental Education

EEF: Education Endowment Foundation

EEG: Electroencephalography

EF: Executive Functions

EFA: Education for All

EFL: English as a Foreign Language

EfS : Education for Sustainability

EI: Education International

EN: Educational Neuroscience

ePEN: Electronic Performance Evaluation Network

ESD: Education for Sustainable Development

ESE: Environmental and Sustainability Education

FEC: Futures of Education Commission

fMRI: functional Magnetic Resonance Imaging

fNIRS: functional Near-Infrared Spectroscopy

GHI

GDP: Gross Domestic Product

GEB: General Ecological Behaviour

GHG: Greenhouse Gas

GIFT: Generalized Intelligent Framework for Tutoring

GIRFEC: Getting It Right For Every Child

GNP: Gross National Product

GPE: Global Partnership for Education

GWAS: Genome-Wide Association Study

HCT: Human Capital Theory

IPCC: Intergovernmental Panel on Climate Change

IPS: Intraparietal Sulcus

IQ: Intelligence Quotient

IRT: Item Response Theory

ISEE Assessment: International Science and Evidence based Education Assessment

ISTE: International Society for Technology in Education

JKL

J-PAL: Abdul Latif Jameel Poverty Action Lab

KBS: Keep Back Straight

LA: Learning Analytics

LAC: Latin American Country

LATAM: Latin America

LGBTQ+: Lesbian, Gay, Bisexual, Transgender, Queer or Questioning

LMICs: Low- and Middle-Income Countries

LTD: Long-Term Depression

LTP: Long-Term Potentiation

LUOTS: Lightning Up the Old Train Station

MNO

MA: Millennium Ecosystem Assessment

MBE: Mind, Brain and Education

MDES: Minimum Detectable Effect Size

MDG: Millennium Development Goal

MEG: Magnetoencephalography

KEY ACRONYMS

MOOC: Massive Open Online Course

MRI: Magnetic Resonance Imaging

MTSS: Multi-Tier Systems of Support

NAPLAN: National Assessment Program – Literacy and Numeracy

NCEE: National College Entrance Exam

NCLB-Act: No Child Left Behind-Act

NCP: Nature's Contribution to People

NEA: National Education Association

NEP: New Ecological Paradigm

NGO: Non-Governmental Organization

NRC: National Research Council

OECD: Organisation for Economic Co-operation and Development

PQRS

PBL: Project Based Learning

PE: Physical Education

PERMA: Positive Emotions, Engagement, (positive) Relationships, Meaning, and Accomplishment

PET: Positron Emission Tomography

PFC: Prefrontal Cortex

PGS: Polygenic Score

PISA: Programme for International Student Assessment

PISA-D: PISA for Development

POC: People of Colour

POE: Post Occupancy Evaluation

PTE: Pearson Test of English

PTSD: Post-Traumatic Stress Disorder

R&D: Research and Development

RAN: Rapid Automatized Naming

RCP: Representative Concentration Pathways

RCT: Randomized Controlled Trial

RD: Reading Disorder

REM: Rapid Eye Movement

ROI: Return on Investment

RtI: Response to Intervention

SCS: Sustainable Community Schools

SDG: Sustainable Development Goal

SDM: Summary for Decision-Makers

SEAL: Social and Emotional Aspects of Learning

SEF: Stage–Environment Fit

SEL: Social and Emotional Learning

SEND: Special Educational Needs and Disabilities

SES: Socio-economic Status
SLD: Specific Learning Disability

SMART: Stress Management and Resiliency Training

SNP: Single Nucleotide Polymorphisms

SOGIE: Sexual Orientation and Gender Identity Expression

STEAM: Science, Technology, Engineering, Arts and Mathematics

STEM: Science, Technology, Engineering, and Mathematics

TUV

TALIS: Teaching and Learning International Survey

TBI: Traumatic Brain Injury

TFI: Teach for India

ToM: Theory of Mind

TPB: Theory of Planned Behaviour

TPJ: Temporoparietal Junction

UDL: Universal Design for Learning

UK (or U.K.): United Kingdom

UKABIF: United Kingdom Acquired Brain Injury Forum

UN: United Nations

UNCRC: United Nations Convention on the Rights of the Child

UNDESA: United Nations Department of Economic and Social Affairs

UNDESD: United Nations Decade of Education for Sustainable Development

UNEP: United Nations Environment Programme

UNESCO: United Nations Educational, Scientific and Cultural Organization

UNESCO MGIEP: UNESCO Mahatma Gandhi Institute of Education for Peace and Sustainable Development

UNFCCC: United Nations Framework Convention on Climate Change

UNICEF: United Nations International Children's Emergency Fund
UNPF: United Nations Population Fund

UNPFA: United Nations Fund for Population Activities

USA: United States of America

USSR: Union of Soviet Socialist Republics

VRU: Violence Reduction Unit

VS: Ventral Striatum

VUCA: Volatile, Uncertain, Complex and Ambiguous.

WXYZ

WEIRD: Western, Educated, Industrialised, Rich and Democratic

WG1: Working Group 1 (of the ISEE Assessment)

WG2: Working Group 2 (of the ISEE Assessment)

WG3: Working Group 3 (of the ISEE Assessment)

WG4: Working Group 4 (of the ISEE Assessment)

WHO: World Health Organization

WSSD: World Summit on Sustainable Development

WWF: World Wide Fund for Nature

ZPD: Zone of Proximal Development

GLOSSARY

WORKING GROUP– 3

ABC

Academic knowledge

Academic knowledge (or skills) refers to knowledge and skills in domains such as numeracy, literacy, science, physical education, and the arts.

Achievement emotions

In the context of learning and education, achievement emotions relate to achievement activities and their success and failure outcomes, such as enjoyment of learning, hope for success, or anxiety before an exam.

Amygdala

The amygdala is a subcortical brain structure and is part of the limbic system (as are the hypothalamus and hippocampus). The amygdala is critical for learning (e.g., forming memories) about the emotional significance of (positive and negative) stimuli, emotion processing and emotional responses, but has also been implicated in processes such memory processing, motivation, anticipating reward, and decision making. The amygdala - therefore - is involved in all learning, most notably social-emotional learning. Furthermore, the amygdala is closely linked to activity of the HPA-axis. See also: hippocampus, HPA-axis.

Anterior cingulate cortex

The anterior cingulate cortex (ACC) is a brain region involved in various complex cognitive functions such as error detection, attention, decision-making, empathy, cognitive/impulse control and affect regulation. The ACC has connections to both the limbic system and the prefrontal cortex.

Anthropocene

The term 'Anthropocene' refers to the period of time during which human activity started to influence planetary systems in highly detrimental ways.

Biological/intrinsic Determinism

Intrinsic biological determinism, or bio-determinism, refers to the viewpoint that biological processes and endowments (such as one's DNA) serve as a blueprint for an individual's future development and outcomes. This viewpoint infers a lack of environmental influences and limited human agency.

Character education

Character education refers to the education of one's character, e.g., morality. Character education carries a political connotation and works on an assumption that morality takes the form of supposedly universal conservative 'virtues' such as self-control, loyalty, and obedience. Character education tends to view individuals' characters as both the cause of as well the solution to a wide variety of social problems including poverty, poor educational outcomes and the gender pay gap, thereby 'responsibilizing' the individual.

GLOSSARY
WORKING GROUP- 3

Cognition

Cognition is the mental process involved in knowing, understanding and learning.

Cognitive empathy

Cognitive empathy is the ability to put oneself in 'other people's shoes' (perspective taking) to understand their thoughts, intentions and actions.

Computational neuroscience

Computational neuroscience is a (research) area of neuroscience that uses mathematical tools and theories to study the brain.

Cortex

The (cerebral) cortex is the folded outer layer of the brain. The cortex is usually subdivided into different lobes: the frontal lobe, the parietal lobe, the temporal lobe and the occipital lobe. The frontal lobe is significantly involved in learning and has been linked to processes such as working memory, inhibition and cognitive flexibility, which are crucial for the learning process. Deeper in the brain, under the cortex, lie subcortical/ allocortical brain structures such as the amygdala, hypothalamus, and hippocampus. Note that different functions have been associated with different brain regions, but most complex functions such as learning or memory rely on networks of interconnected – rather than individual – brain regions.

Culture

Culture is typically understood as values, belief systems and practises shared by groups.

Cumulative risk model

Cumulative risk models account for risk factors in a cumulative manner. It shows that the cumulation of risk factors explains substantially more variance in outcomes (e.g., education and learning) than a single risk factor.

Curriculum

The curriculum is an organising device that influences the way knowledge is framed and presented in the context of schools.

See also: teaching and learning

DEF

Dyscalculia

Dyscalculia is a specific learning disability characterised by persistent difficulties in processing numerical information and acquiring basic arithmetic skills.

Dysgraphia

Dysgraphia is a specific learning disability characterised by persistent difficulties in acquiring handwriting, spelling skills, or both, despite adequate schooling.

Dyslexia

Dyslexia is a specific learning disability characterised by persistent difficulties in learning to read words and poor decoding, the process by which words are sounded out through letter-sound association.

Dynamic assessment

Dynamic assessment (feedback while the test is being conducted), originally, is a highly deliberate sequence of assessment and teaching, where the baseline assessment is followed by targeted teaching with corrective feedback (and often multiple teaching-assessment components), culminating in a final assessment. The main premise of dynamic assessment is its capacity to establish the level of students' performance by characterising their current level of knowledge, following their progress as they acquire new knowledge, and appraising their learning potential as new learning tasks are formulated.

Education

Education is a societal process that shapes human behaviour and social action. It stands for three central types of activities of teachers and students, namely teaching, learning and evaluation, that each express a particular relationship with the actors involved. Education can be framed as a broad, complex system consisting of a set of human and non-human elements and the relationships between them, e.g., teacher-student, self-other, self-self, self-society, self-ecology. Human elements include students, teachers, administrators, parents, policymakers, stakeholders and various others. Non-human elements comprise learning spaces - classes, schools, virtual, outdoor, textbooks, etc. The term complex system entails the presence in the system of a group of multiple components working both independently and interdependently that prevent the system from being fully controlled and predicted, hence it is bound to evolve in unexpected ways.

Emotions

Emotions in the context of education and learning include (among others) negative emotions such as anxiety, anger, shame, boredom, and hopelessness and positive emotions such as enjoyment, curiosity, hope and pride.

Emotion Regulation

Emotion regulation refers to recognizing and managing emotions

Emotional intelligence

Emotional intelligence refers to the ability to identify, use and manage one's own and other persons' emotions.

Emotional (Affective) empathy

Emotional Empathy and Affective Empathy are used interchangeably and defined as the capacity to respond with an appropriate emotion to another's mental states. It is based on emotional contagion.

GLOSSARY
WORKING GROUP- 3

Empathy

Empathy is an emotion through which one shows compassion for another person's distress. Empathy also refers to the ability to understand and share the emotional and cognitive states of others. It is a key social relational function that acts as a pathway to higher-order prosocial behaviour, including bonding and forming meaningful relationships, cooperation, and moral decision-making.

Epistemic emotions

In the context of learning and education, epistemic emotions are generated by the cognitive response to learning materials, such as surprise, curiosity, and confusion.

Environmental injustice

Environmental injustice refers to the observation that those who are marginalised, poor, racialized, and Indigenous, in both more developed countries and less developed countries, bear the burden of environmental risks, such as pollution, climate change, and exploitation of their land and natural resources.

Epigenetics/Epigenotype

Epigenetics is the process by which environments affect the molecular level of human bodies by regulating gene expression, and therefore affect phenotypical behaviours and traits without changing DNA itself.

Research in epigenetics is interested in how social environments affect gene expression. Epigenetics proposes that the environment, including material and social factors, plays an important role in shaping how genes work within human lifetimes and across generations.

Eudaimonic theory of well-being.

Eudaimonic theories of well-being suggest that persons live a life of well-being if they realise goods that are deemed to be objectively good for all people or if they develop or have developed their human capacities to the full (i.e., functioning well).

Executive functions

Executive functions are a class of cognitive processes that are thought likely to facilitate academic performance. Executive function abilities are defined as a set of separable, but overlapping, cognitive skills comprised of: 1) working memory, defined as the ability to hold information in mind and update it; 2) inhibitory control/response inhibition, defined as the ability to inhibit a highly learned response to a stimulus in favour of a less dominant response; and 3) cognitive flexibility/set shifting, defined as the ability to attend to distinct but closely related aspects of a given set of stimuli, such as the ability to group a set of objects by the dimension of colour and then by the dimension of shape. Collectively, these skills enable individuals to focus attention, regulate impulses, switch between competing demands, and engage in goal-directed activities.

Explicit learning

Explicit, visible and measurable learning is learning such as prioritised in curricula or measured through assessment outcomes. Compare with: implicit learning.

Extrinsic motivation

Extrinsic motivation involves investing effort in order to avoid failure.

Family-School Partnerships

Family-school partnerships refer to alliances in which families and professionals confidently build on each other's word, judgement, and wise actions to increase educational benefits to students and themselves. Family-school partnerships are conceptualised as relationships that encompass and surpass parent/family involvement and engagement. Whereas "involvement" refers to families merely taking part in an activity, partnership embodies equity, mutual responsibility, and commitment.

Fixed mindset

A fixed mindset is the belief that abilities (e.g., intellectual abilities) are set and unchangeable.

Formal education

Formal education refers to the structured education system that runs from primary (and in some countries from nursery) school to university, and includes specialised programmes for vocational, technical and professional training.

Formative assessment

Formative assessment or "Assessment for Learning" is a form of educational assessment used to (daily) monitor students' learning progress and provide feedback over the course of an instructional unit to identify students' learning needs and adjust teaching accordingly to improve students' achievement and enhance ongoing learning.

GHI

Gene-environment interactions

Gene (or genetic)-environment interactions refer to the finding that individual genetic makeup interacts with one's personal (e.g., educational, socioeconomic, etc.) experience.

Social Genomics

Social genomics refers to research methods where genomics methods and insights converge with social scientific modes of analysis.

GLOSSARY
WORKING GROUP- 3

Global North and Global South

The Global North and Global South (or North–South divide) is a political and socio-economic division of Earth popularised in the late 20th century roughly based on the categorisation of the countries by their economic and developmental status. Generally, definitions of the Global North include Australia, Canada, Israel, Japan, New Zealand, Singapore, South Korea, Taiwan, the United States, and almost all the European countries. The Global South is made up of Africa, Latin America and the Caribbean, Pacific Islands, and most of Asian countries, including the Middle East.

Grey matter

Grey matter makes up the folded outer layer of the brain (i.e., the cortex) and consists mostly of neuronal cell bodies and glial cells.

See also: white matter.

Grit

Grit refers to the persistence and passion that underlie goal-oriented behaviours towards a larger superordinate goal and have been linked to learning in several contexts.

Growth mindset

A growth mindset is the belief that abilities (e.g., intellectual abilities) can be developed and improved through, for example, dedicated effort and learning.

Health

Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity' (World Health Organization, 1948).

Hedonic theory of well-being

Hedonic (or subjective) theories of well-being equate well-being to having positive emotions about life and presume that individuals themselves are the judges of their well-being (i.e.., 'feeling well').

Hippocampus

The hippocampus is a brain structure located in the allocortex and is part of the limbic system (as are the amygdala and hypothalamus). The hippocampus is primarily involved in memory processes and learning. Furthermore, the hippocampus is closely linked to activity of the HPA-axis. See also: amygdala, HPA-axis.

Holistic learning

The purpose of holistic learning is to seek a balance between the different dimensions of the being: the body, the intellect, the emotional and the spiritual, as necessary conditions for wellness.

HPA-Axis

The Hypothalamic Pituitary Adrenal (HPA)-Axis is a biological stress system

(i.e., neuroendocrine system) that controls reactions to stress as well as many body processes. HPA-axis activity follows a circadian rhythm and is activated in response to cognitive (e.g. fear, excitement, anxiety) or non-cognitive (e.g. infections) stressors. Furthermore, the HPA-axis is closely linked to activity of the amygdala and hippocampus. See also: amygdala, hippocampus.

Human Flourishing

Human flourishing is both the optimal continuing development of human beings' potentials and living well as human beings. Living well as a human being means being engaged in relationships and activities that are meaningful, i.e. aligned with both their own values and humanistic values, in a way that is satisfying to them. Flourishing is conditional on the contribution of individuals and requires an enabling environment (e.g., fulfil basic biological and existential needs. It can be regarded as a particular interpretation of well-being. Furthermore, flourishing involves community and is an interpersonal, not a personal pursuit.

Hybrid learning spaces

Hybrid learning spaces are 1) physical learning spaces (with virtual aspects), and virtual learning spaces (with physical aspects), with understandings of the latter being contributed to from learning sciences, computer supported collaborative learning and human computer interaction studies.

Implicit (or hidden) learning

Implicit or hidden learning is learning that extends beyond the explicit curricula of education. Compare with: explicit learning

Inclusive education

Inclusive education is a human-rights based approach to education where there is respect for diversity and all members of the learning community are welcomed equally. The central idea of inclusive education is that each student receives the best and most comprehensive education that is appropriate for their needs, and that all students must feel valued, respected, included and listened to. Note that inclusive education is an approach to education, and not necessarily a place. Inclusive education does not mean that a student cannot get specialised help outside the classroom walls. Compare with: special education.

Informal education

Informal education or learning, refers to activities such as free or guided play (e.g., role-playing, singing, counting games) and creative activities, which are closely linked to learning and development in childhood and beyond.

Informal learning

Informal learning is the process by which people acquire knowledge, skills, and attitudes through everyday experience and

exposure to the environment in which they live. See also: informal education

Interdisciplinary/Multidisciplinary/Transdisciplinary

Three terms used interchangeably in the ISEE which refer to combining and/or involving several academic disciplines or professional specializations in assessing education and learning.

Intersectionality

Intersectionality refers to a tool to examine the dynamic and complex ways in which people's multidimensional experiences based on e.g., race/ethnicity, class, gender, sexuality, ability, citizenship, and religion, shape identities and social opportunities. Intersectionality examines the influence of power in shaping people's multidimensional lives by expanding the examination of identity categories beyond simplistic, static, one-dimensional, and additive approaches to understanding the simultaneous and mutual factors of social location and structural disadvantage.

JKL

Learning

Learning refers to coming to make sense of what one is taught and happens when students' potentialities are evoked to come to understanding in agential ways of being and acting. Learning would fail to be learning, if students' potentials are not evoked in the quest to gain understanding, insight, and be encouraged to embark on an academic, political, economic, social and environmental journey with a quest for human flourishing. The broad perspective of learning encompasses both learning as process, as experience, and as outcomes. Learning is a process of active meaning-making situated in context, based on which relatively permanent changes occur within any one or more of the following: human dispositions, capabilities, knowledge, behaviours, values, attitudes, and/or preferences. Learning thus involves relational, embodied, affective and non-conscious ways of knowing and is inherently social, emotional, relational and affective. Learning is heavily influenced by cognitive, emotional, motivational and social brain processes that are all interdependent, as well as by culture (e.g., value and belief systems and practises shared by groups) and other environmental factors (e.g., socio-economic status/SES). See also: learning experience.

Learning analytics

Learning analytics refers to the collection of multiple forms of data from a variety of learning platforms and apps, in order to diagnose and predict dimensions of educational performance, and ultimately produce "actionable insights" of immediate and demonstrable instructional effectiveness.

(Specific) Learning disability

A (specific) learning disability (SLD) traditionally refers to any (neurobiological) condition that impairs a child's ability to learn. They arise when persistent difficulties acquiring academic skills are unexpected in the context of age and grade level standards. Most common learning disabilities are in the areas of reading (dyslexia), mathematics (dyscalculia), and/or written expression (developmental coordination disorder or dysgraphia). This 'pathology', 'deficit', or 'medical' model views neurological differences as impairments and deficits, and has recently been complemented with the view of atypical learning or neurodiversity. See also: atypical learning, neurodevelopmental disorder, neurodiversity

Learning experience

Learning experience by the International Bureau of Education (UNESCO) is defined as "A wide variety of experiences across different contexts and settings which transform the perceptions of the learner, facilitate conceptual understanding, yield emotional qualities, and nurture the acquisition of knowledge, skills and attitudes. Thus, the learning experience at the individual level is intrinsically cognitive, emotional and social. In educational settings learning experiences are ideally challenging, interesting, rich, engaging, meaningful, and appropriate to learner needs. Previous learning experiences are considered to be key factors predicting further learning". See also: learning.

Learning places

Learning places indicate identifiable or particular settings in which education and learning take place, such as a classroom, a school, a neighbourhood, a territory. See also: learning spaces.

Learning spaces

Learning spaces are physical (built or natural) and digital spaces or sites in which education and learning occurs, e.g., schools, outdoors, nature, virtual/digital. Furthermore, 'spaces' here can be understood as the way in which geography shapes social relations and practises, connecting things and people. See also: learning places.

Learning trajectories

Learning trajectories are descriptions of children's thinking as they learn to achieve specific goals in an academic domain (e.g., mathematics), and a related, conjectured route through a set of instructional strategies and activities designed to move children through a developmental progression of levels of thinking. See also: Pillars of Learning

Long-term Depression

The weakening of a postsynaptic electrical response in the brain.

Long-term Potentiation

The strengthening of a postsynaptic electrical response in the brain.

MNO

Metacognition

Metacognition is "thinking about thinking" or "learning to learn" and refers to processes such as monitoring of attention, emotion and behaviour. Students can use metacognitive processes and strategies to monitor and reflect on their own learning.

Mindset

An individual's mindset is the beliefs about the nature of human attributes (e.g., intelligence) that affect one's actions.

Motivation

Autonomous/Intrinsic motivation

Autonomous, or intrinsic, motivation involves being motivated by inherent interest and enjoyment in an activity, or by internal endorsement of the activity and its importance.

Neuroplasticity

Neural plasticity (or neuroplasticity) refers to the anatomical and functional changes of the brain underlying cognitive and behavioural changes during development in relation to place, time and context-specific experiences or in response to an intervention, e.g. learning or training.

Neurocentrism

Neurocentrism, or neurocultures, is a viewpoint based on the idea that the brain is conceived as the foundation of many aspects of human nature and social life and where the ability to know key truths about the self and the social are dependent upon developments in neuroscience.

Neurodevelopmental disorder

Neurodevelopmental disorders encompass a broad array of (often co-occurring) disorders that involve impaired development of cognitive or motor functions manifest from childhood. There is no consensus across different diagnostic and classification systems for what is considered a neurodevelopmental disorder, but these tend to include specific learning disabilities (SLDs), communication disorders, motor disorders, autism spectrum disorder (ASD), attention deficit hyperactivity disorder (ADHD), tic disorders, and intellectual disability. See also: (specific) learning disabilities

Neurodiversity

The concept of neurodiversity emphasises that variation in neurodevelopment leads to strengths as well as impairments, and

that children with disabilities are not inferior to their typically developing peers. From the neurodiversity perspective, 'disorders', such as autism and ADHD, are seen as variations in brain structure and function, which lead to ways of thinking and behaving that are different from most people in society.

Neuromyth

A neuromyth refers to a misconception generated by a misunderstanding, a misreading or a misquoting of facts scientifically established (by brain research) to make a case for use of brain research, in education and other contexts. Neuromyths, broadly, are overly simplified facts about the brain which lead to suggestions about learning in general as well as teaching practises that are incorrect. Their mythical status means they are enduring: even when the claims are repeatedly shown to be false, they continue to circulate as scientifically based truths.

Neuroscience

Neuroscience, as a field or research, includes neurochemistry, molecular biology, electrophysiology, neuroanatomy, neurophysiology, and neural network studies.

New materialist (or posthuman) approach to pedagogy

The new materialist (or posthuman) approach to pedagogy and learner

experience speak to creative teaching and learning methods that embed the learner within their local places, contexts and materialities, dissolving the old binaries between humans and nature, children and their everyday worlds. Although there is no single definition of New materialism, the term is often used to describe a theoretical turn away from the persistent dualisms in modern and humanist traditions whose influences are present in much of cultural theory.

Non-formal education

Non-formal education refers to planned, structured programmes and processes of personal and social education for young people designed to improve a range of skills and competences, outside the formal educational curriculum.

PQRS

Prefrontal Cortex

The prefrontal cortex (PFC) is a brain region located at the front of the frontal lobe. The PFC linked to a variety of complex behaviours and processes such as metacognitive skills including monitoring of attention, emotions and thinking patterns, and executive functioning skills (e.g., working memory, inhibition/cognitive control and cognitive flexibility). The PFC regulates the activity of the limbic system (see Amygdala and Hippocampus). See also: frontal lobe,

executive functioning skills.

Prerequisite/foundational skills

Prerequisite, or foundational, skills are skills acquired in non-school and school contexts that are important for acquiring new knowledge throughout school. Examples are vocabulary, letter and number knowledge.

Play

Play is a multi-faceted concept which can be thought of as a disposition, attitude or activity that is voluntary (i.e., undertaken for one's own sake), pleasurable and intrinsically motivating. Play can be scaffolded by skilled adults (guided play) or independent (free play). With reference to education and learning, play is often part of informal educational practises.

Polygenic (risk) scores

A (genome-wide) polygenic score (PGS), or polygenic risk score, for educational attainment is an aggregate data-score calculated from information about a person's personal GWAS outcomes i.e., genetic loci that are associated with educational attainment, cognition and learning environments. Polygenic scores for educational attainment summarise how much of the total variance in educational attainment is influenced by differences in genetic loci. See also: GWAS and PGS.

Pruning, synaptic

Synaptic pruning is a process through which unnecessary connections in the brain are eliminated, thought to aid in making information processing more efficient.

Randomised Controlled Trial (RCT)

A Randomised Controlled Trial is a research design in intervention research which offers (insight into) causal inference.

SDG4.7

At the 70th Session of the UN General Assembly in September 2015, member states adopted the 2030 Agenda for Sustainable Development. It aimed to engage the nations of the world towards collectively promoting sustainable development, decrease global inequalities, and realise universal quality education. At the heart of the Agenda were 17 SDGs, including SDG 4, which covers education seeking to 'ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.' In SDG4.7, it is highlighted that by 2030 it should be ensured that all learners acquire knowledge and skills needed to promote sustainable development, including among others through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship, and appreciation of cultural diversity and of culture's contribution to sustainable development.

evidence (WG1-3)

Social emotions

In the context of learning and education, social emotions relate to teachers and classmates, such as compassion, admiration, contempt, envy, anger, or social anxiety in the classroom.

Self-Awareness

Self-awareness (in the context of social and emotional learning) refers to the ability of a person to accurately recognize their emotions and thoughts, and understand how these influence their behaviour.

Social neuroscience

Social neuroscience explores the ways brain structure and functioning are affected by social and environmental factors. Social neuroscience focuses on the brain's function in its social context. As a field, it investigates how the brain supports 'communication, social perception and recognition, impression formation, imitation, empathy, competition, cooperation, pair-bonding, mother-infant attachment, bi-parental caregiving, social learning, status hierarchies, norms and cultures, social learning [sic], conformity, contagion, social networks, societies, and culture'

Self-Determination Theory

Self-determination theory is a 'needs' theory of motivation positing that humans have three universal psychological needs, namely: the need for autonomy, the need for competence, and the need for relatedness, which promote optimal human functioning and well-being. The need for autonomy is satisfied when behaviour, feelings and thoughts are experienced as one's own choice and self-endorsed. The need for competence describes a sense of mastery in activities that one considers important. The need for relatedness concerns the sense of connectedness with those who are important to an individual, in the school-context e.g., teachers and peers at school.

Social psychology

Social psychology is concerned with how individual thoughts and cognitive processes are shaped by social contexts, interactions and influences.

Self-regulation

Self-regulation refers to skills to regulate behaviour, emotions, and thoughts in the pursuit of long-term goals, and include the ability to delay gratification, pay attention, and control impulsivity.

Science

Science is the pursuit and application of knowledge and understanding of the natural and social world following a systematic methodology based on

Social Emotional Learning (SEL)

Social emotional learning (SEL)

involves the processes through which people acquire and effectively apply the knowledge, attitudes, skills and competencies to recognize, understand and manage their emotions, feel and show empathy, care and concern for others, establish and achieve positive goals, develop and maintain positive relationships, make responsible decisions and handle challenging situations.

Special education

Special education provides schooling to students with disabilities (both physical and psychological in nature) in separate educational settings from that of their peers without disability. On its extreme end, children with disabilities are taught in special schools according to their disability. Additionally, these children are often congregated into segregated classrooms according to their disability. Compare with: inclusive education.

Systemic Social Emotional Learning (SEL)

Systemic SEL is an approach to create equitable learning conditions that actively involve all Pre-K to Grade 12 students in learning and practising social, emotional, and academic competencies.

Summative assessment

Summative assessment or "Assessment of Learning" is a form of (often standardised) educational assessment typically given at the end of an instructional unit (e.g., a course or grade level) to assess student learning outcomes in order to find out whether they have attained a predefined set of standards, expectations or instructional goals, or as a selection method to follow-up educational tracks or the labour market. In addition to evaluating learners, summative assessment also describes the process of evaluating the effectiveness of sequences of instructional activities to provide information for judging the overall value of an education program - as well as for ranking schools and education systems.

TUV

Topic emotions

In the context of learning and education, topic emotions pertain to the topics presented in class, such as empathy with the characters portrayed in a novel.

Transformative Social Emotional Learning (SEL)

Transformative SEL is concerned with advancing equity in access to resources and outcomes in education. Transformative SEL competencies focus on identity, intersectionality, agency, belonging and engagement as central to furthering social-emotional development and achieving equity in education.

WXYZ

Well-being

Well-being is a multidimensional construct covering anything from cognitive appreciation of one's satisfaction with life up to subjective, highly affective experiences of happiness. In the ISEE Assessment, well-being is seen as an umbrella term of the two central concepts happiness and flourishing.

White matter

White matter is a fatty layer on the brain consisting of an insulating myelin sheath which aids in faster transmission along axons.. Compare with: grey matter.

Zone of Proximal Development

Vygotsky's zone of proximal development (ZPD) indicates an area of sensitivity that measures what a child can do on her/his own and what she/he can do with assistance of a more experienced other such as adults, peers and digital tools.
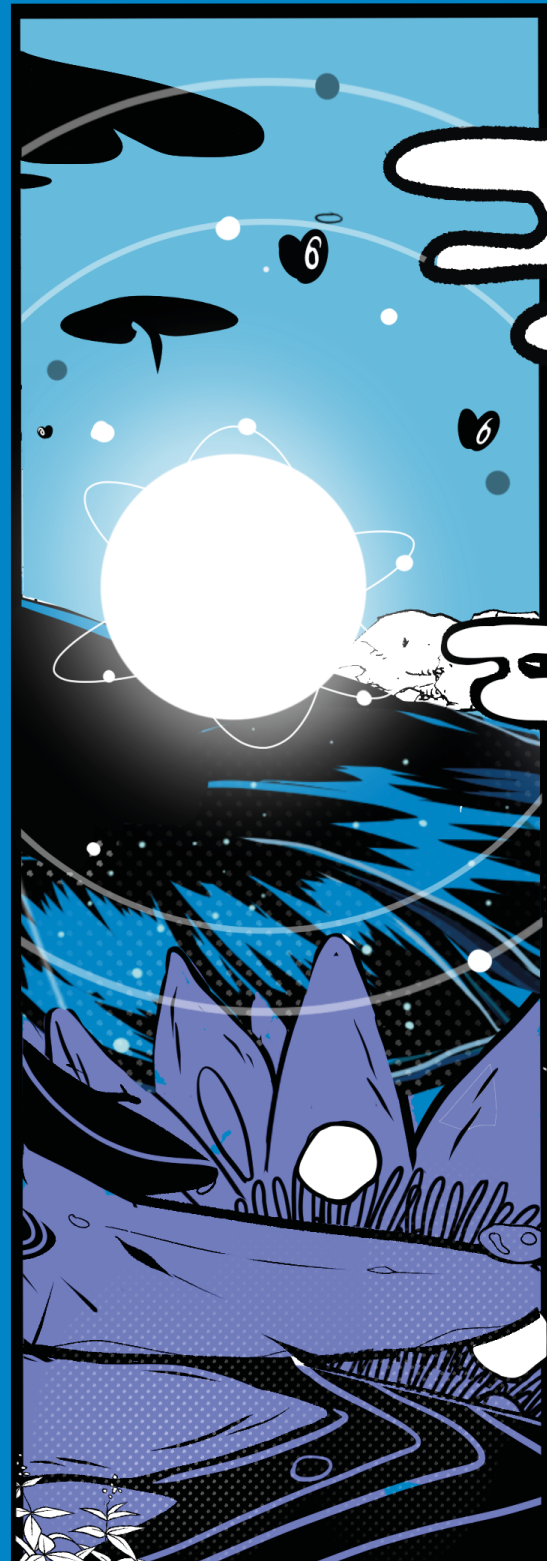
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