Foundations of academic knowledge

Book Section

WORKING GROUP 03

CHAPTER

5

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Abstract:

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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WORKING GROUP 03

5

CHAPTER

5.1 How do we understand the relationship between brain and cognitive development and the acquisition of academic knowledge and skills?

Developmental journeys involve detours, regressions and complex interactions.

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 adverse development on the other.

Debates about the content and purpose of school curricula abound; what and whose knowledge should be taught in schools is an ongoing debate.

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.

5.1 .2

KNOWLEDGE AND CURRICULUM

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 discussion)**. 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 disenfranchize 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 that disciplinary knowledge is generated by social and scientific groups, it follows that curricula can change and should be

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.

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 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

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.

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 underplayed, invisible and discounted in schools **(Hackett, MacLure and McMahon, 2020)**

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.

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

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.

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.

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 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

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learning potential **(Jeltova et al., 2007)**. One such approach involves dynamic assessment (DA) **(see text box 'Dynamic assessment')**. While assessment is discussed in more detail in **WG2-ch9**, here we emphasize that formative assessment is critical to support student learning.

DYNAMIC ASSESSMENT

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 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.

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.

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 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)**.

...acknowledge that current debates challenge Western epistemologies and raise questions of what counts as formal knowledge acknowledge that current debates challenge Western epistemologies and raise questions of what counts as formal knowledge.

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; 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

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turn.

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

Helping students learn with authentic tools and strategies protects against the pedagogies that emphasize assessment rather than the retention of knowledge.

practicing retrieval. It can bring about: increased learning and 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 students 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

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)**.

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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, mankind 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, through that, gain access to

The prerequisite skills of phonemic awareness and letter knowledge are key precursors...

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

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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 to 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)**.

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

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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.

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 becomes 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)**, Vierhaus et al. **(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.

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 andLonigan, 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.

...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

Metalinguistic knowledge and many prerequisite literacy skills acquired in mother tongue are transferable...

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 in colonial languages imposes mastery of that language as a

...'multiliteracy' embraces the socially situated and multifaceted nature of literacy practices in diverse cultures and communities.

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; Erstadet al.,2020)**, as well as interactive features and gesture- and speech-responsive interfaces **(Walsh and Simpson, 2014)**.

Multiliteracy skills involve learning to think creatively and critically about diverse approaches...

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; Flewittand Clark, 2020)**. Developing multiliteracy skills refers to having opportunities to practice 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 that are linked to the concepts and ideas to be taught. Neuroscientific

...there is a shift towards recognizing the importance of multiple senses for perception and learning.

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.

WORKING GROUP 03

5

CHAPTER

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

...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.

arithmetic ability when they enter 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

Geometric measurement is an important real-world area of mathematics that can also help develop other areas of mathematics, including reasoning and logic.

can be broken down into multiple 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 also in modern Welsh, numbers larger than ten are constructed

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.

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., 2020)**. This may be due to the fact that numbers in Chinese can be

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.

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' vs. '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 vs. Hindi), and not when the language differences were relatively small **(e.g. English vs. 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 and Sarama, 2004)**. Learning trajectories include information

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.

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)**.

5.4.4

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

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.

to mathematics as a human 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)**.

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

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.

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 **(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

The urgency of climate change provides a focus to accelerate the translation of these existing pedagogical principles into educational praxis.

an understanding of the power and limits of science as a lens for knowing the world that interacts with public literacy and trust.

5.5 .2

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 natural 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).

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 **(Crinalland 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)**.

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.

...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 activist 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

As teachers have long known, music can be used as a tool for aiding comprehension in the classroom by setting words to songs.

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 emotion. To promote long-term

Engagement in music has been found to regulate emotions and promote social bonding from infancy to adolescence.

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; Telamaet al., 2014; Hayeset 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-**

...poorly implemented PE has the potential to negatively impact self-esteem and increase the incidence of bullying.

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 Cliff, 2018; OECD, 2020)**. For younger children (e.g. in the foundation

...participation in physical activity tends to decline as children enter adolescence, and this is particularly so for girls.

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 development of spoken language

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.

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

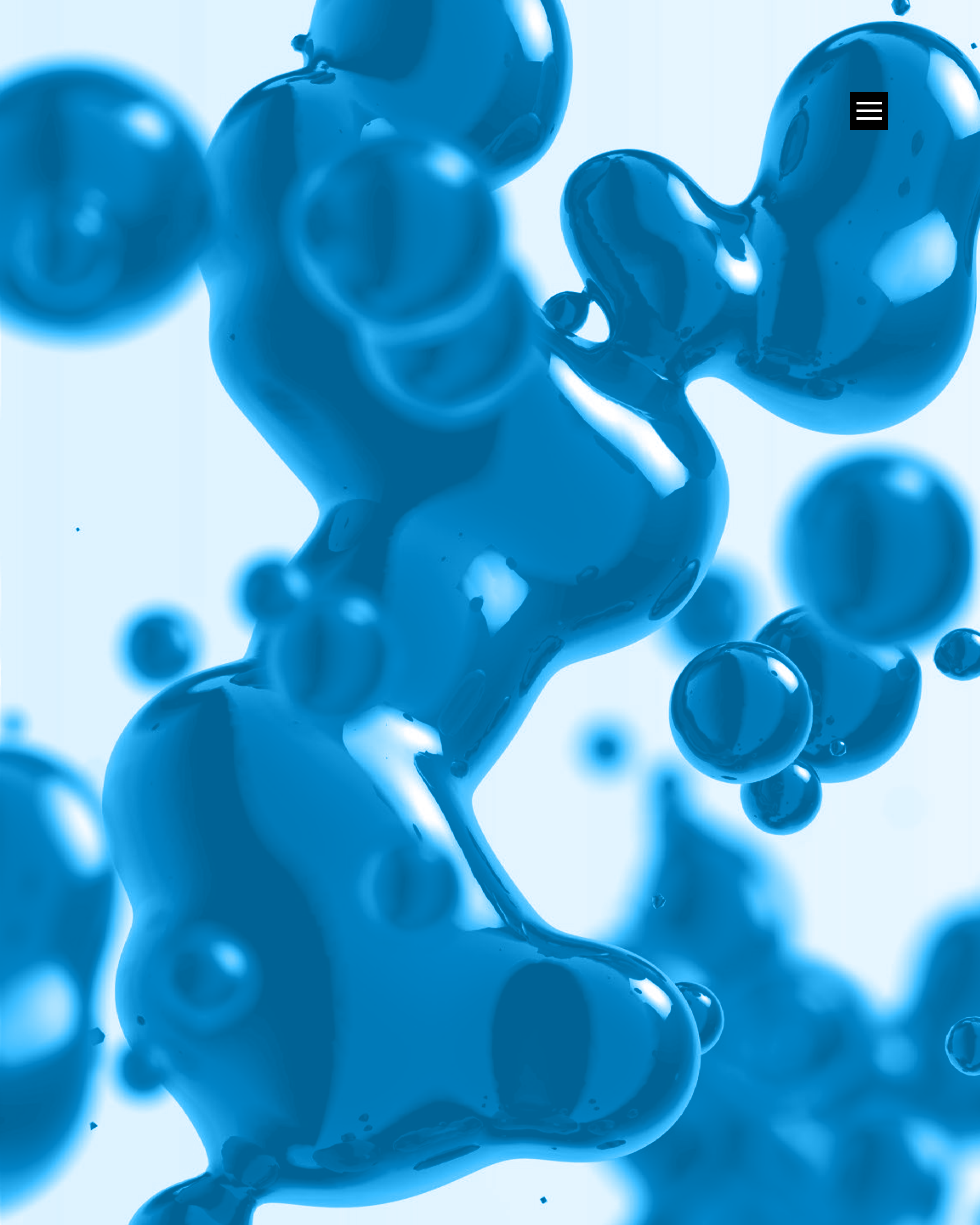
IMPLICATIONS

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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