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Childhood Development, Learning, and Education: A Focus on Nonlinear Learning and Play

Review Article

Gowda VK[1]*, Ravi Kumar CP[2], Goyal R[3], and Sidhwani S[4]

[1]*Department of Paediatric Neurology, Indira Gandhi Institute of Child Health, Bengaluru, India.*

[2]*Consultant Paediatric Neurologist, Aster NEUKIDS, Aster CMI Hospital, Bengaluru, India*

[3]*Clinical Psychologist, Department of Psychology, Kidicious, Delhi, India.*

[4]*Psychotherapist and Psychologist, Department of Psychology, Reality and You Foundation, Mumbai, India.*

***Corresponding author:** Vykuntaraju K Gowda, Department of Paediatric Neurology, Indira Gandhi Institute of Child Health, Bengaluru, India. E-mail Id: drknvraju08@gmail.com

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Abstract

The brain undergoes rapid development during the first 8 years of life and is highly receptive to promotive experiences and stimulation. Early childhood presents a critical window of opportunity to promote early learning and holistic growth and development in children. However, many children, especially those from disadvantaged backgrounds, lack quality early childhood care and education (ECCE). Psychosocially and emotionally deficient environments and suboptimal ECCE negatively impact a child's developmental trajectory with possibly irreversible consequences. It is crucial to adopt ECCE interventions that promote holistic growth in children to effectively utilise the opportunity that early childhood presents. Exposure to enabling and stimulating early learning experiences that are child-centred, flexible, multifaceted, and intrinsically motivating significantly influences a child's overall developmental trajectory with long-lasting outcomes. Here, we discuss two such learning interventions – nonlinear learning and play-based learning – in the context of ECCE. Growing evidence suggests that brain development itself is nonlinear, and children inherently show nonlinear and unpredictable learning trajectories and unique learning styles influenced by environmental factors. This calls for adopting learning interventions that account for this nonlinearity and provide children with flexibility and agency to choose their learning trajectories and styles. Also, encouraging play in early childhood is beneficial for brain development and provides enriching, hands-on, and deep early learning experiences that promote holistic growth in children. Adopting nonlinear and play-based learning strategies as part of ECCE has the potential to positively influence a child's developmental trajectory and foster the development of relevant skills and competencies for lifelong success and well-being.

Keywords: Brain development; Child development; Early childhood care and education; Early learning; Nonlinear learning; Learning through play

Abbreviations

ECCE-Early Childhood Care and Education

Introduction

The early years of childhood – from birth to 8 years – are critical for optimal child development [1–7]. Around a million neural connections are formed per second in the first few years of life [1,5,6]. This period of neurodevelopment has a strong influence on the ability of children to learn, adapt, and perform tasks [1,5].Early childhood experiences influence brain architecture and establish foundations for lifelong learning, behaviour, and emotional well-being [1–6]. Postnatal experiences during the early years of life shape certain aspects of functional brain development, such as emotions, social behaviour, memory, cognition, and decision-making, that involve prolonged processes of specialisation extending well into childhood and early adulthood [8,9]. The relatively long postnatal period of human brain development provides opportunities for learning, and enriching interactions with the environment during this time foster fine-tuning and shaping of brain circuitry [8].

Neural networks in the brain that underlie learning are shaped and wired based on the interactive influences of both genes and the environment [1,3–5]. While genes determine when these networks are formed, individual experiences influence how networks unfold [3]. This emphasises the importance of enriching stimulation and stable, caring, and interactive relationships between children and their caregivers during early childhood [1,3–5]. Neuroplasticity is at its peak during early childhood when the brain is naturally more flexible and can accommodate various environmental stimuli and interactions. This capacity to adapt generally tends to decrease with age [1,3,4]. Mechanisms of learning and neuroplasticity shape many of the behaviours observed in infancy [8]. Although there are individual differences in children's susceptibility to environmental stress, chronic and toxic stress during early childhood negatively affects the developing nervous system and causes long-term problems in learning, memory, and behaviour [1,3–5].

According to Jean Piaget, a child's cognitive development progresses through the processes of assimilation, in which 'new information or experiences are incorporated into existing cognitive structures', and accommodation, in which 'pre-existing structures adapt to accommodate new information' [10,11]. In this way, children constantly adjust and use new information to comprehend various perceptions and experiences [10–12]. Child development and early learning occur in multiple interactive and mutually reinforcing domains [2,4,13]. Children reach adequate developmental potential when they attain holistic skills across intellectual, social, physical, moral, cognitive, language, and emotional spheres [1,3,7,14]. Developmental interventions in early childhood should take into consideration that the trajectory of child development and learning is influenced not only by health and nutrition but also by other complex and multifaceted factors, such as the nurturing qualities of the environment and psychosocial and emotional experiences [2,12,15].

Early childhood provides a critical window of opportunity during which time the benefits of developmental interventions are amplified [1,4–6,14,15]. One of the United Nations Sustainable Development Goals is to provide quality early childhood development, care, and pre-primary education for all children [5,13,14]. Responsive stimulation and caregiver–child engagement, child-directed and focused enrichment, and quality early learning opportunities both at home and in preschool settings are the essential ingredients for optimal personality and social skills development [1,3–6,13,15–18]. Early learning opportunities and childhood development programmes could improve outcomes in later school years [14,19]. Preschool programmes can promote cognitive development, language development, social competencies, and emotional development [5,15,16]. For example, it has been shown that formal and nonformal or community-based preschools in low-income and middle-income countries improved measures of cognitive and psychosocial development in children [15].

According to data from the United Nations Children's Fund global databases, 2023, only around 40% of children aged 36–59 months attend early childhood education programmes globally [20]. A psychosocially and emotionally deficient environment and suboptimal early childhood care and education (ECCE) can have negative and possibly irreversible consequences for a child's learning and developmental trajectory [3–5,12,20]. Specifically, it disrupts stress response systems and increases the risk of attentional, emotional, cognitive, behavioural, and personality disorders. It is also associated with learning difficulties, impaired executive function, low intelligence quotient scores, and poor reading skills [21]. In India, many young children do not receive quality ECCE, particularly those from socioeconomically disadvantaged backgrounds [22]. There might be a missed opportunity to provide children with an optimal and holistic learning and development foundation during the critical period of early childhood [5,6,20]. High-quality ECCE programmes are recognised as evidence-based interventions that influence nurturing care during the neonatal and early childhood periods [15]. ECCE should ideally incorporate learning interventions that are 'flexible, multifaceted, multilevel, activity-based, and inquiry-based' [7,22]. Here, we will discuss the potential of nonlinear and play-based learning in the context of ECCE.

The Importance of Nonlinear Learning in ECCE

Historically, linear theory has dominated education and influenced decision-making [23,24]. It is often assumed that children progress in an orderly and sequential manner through various stages of development and that there is a direct, proportional cause-and-effect relationship between stimuli and responses [23,24]. Any deviation from this orderly progression is often viewed as an indicator of developmental dysfunctionality in the child [23,24]. However, it is increasingly recognised that nonlinearity and individual variability are inherent characteristics of childhood learning and development [7,12]. Children develop and learn in nonsystematic and unpredictable ways, and each child's developmental trajectory can be both progressive and regressive [7,12,23,24]. Children less than 8 years of age do not follow linear, age-based educational trajectories; they converge in their learning trajectories and start adapting to more structured learning only at around the age of 8 years [7]. Moreover, every child is unique and has their individual growth and development timings and patterns as well as learning styles [7,12,24]. Development and learning are also influenced by social and cultural contexts and various other interacting elements in the child's environment, which may vary from time to time [12]. Small differences in the initial conditions of the learners may yield unpredictable results [23,25,26]. As learning and development are inherently nonlinear, any learning intervention should ideally account for this nonlinearity as well as individual differences among learners [27,28]. It is now recognised that learning in the context of ECCE should be flexible, multilevel, and multifaceted and learners should be given the flexibility and agency to choose their learning trajectories [7].

Evidence suggests that human brain development is a dynamic and nonlinear process [8,29]. In general, sensory and motor systems serving basic functions mature the earliest, followed by temporal and parietal association cortical regions involved in basic language and spatial attention. The higher-order association areas of the brain usually mature last [29,30]. For example, the prefrontal cortex, which is essential for higher-order cognitive functions, is one of the last

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brain regions to mature and continues to develop into adulthood [31]. The density of synapses in the prefrontal cortex increases at around 3.5 years of age and is 2–3-fold higher than the net synaptic density of the adult prefrontal cortex [31]. The process of synaptic pruning (or refinement) in the prefrontal cortex starts during the formative years of childhood, continues through adolescence, and extends into adulthood [31]. Brain volume does not increase uniformly from birth to teenage years; instead, there is varied growth between cortical and subcortical regions as well as between different regions within the cortex [8]. Nonlinear developmental trajectories in both brain structure and function have been reported in various studies [8,30,32–39]. For example, results of a longitudinal study conducted in children after birth and at 1 and 2 years of age revealed that cortical grey matter developed more rapidly in the first year of life compared with the second; total cortical grey matter volume increased 108% in the first year and around 19% in the second year [40]. The results also showed variation in growth rates across cortical and subcortical regions. In the first year, primary motor and sensory cortices had slower growth, whereas association cortices grew more rapidly. In the second year, primary sensory regions continued to demonstrate slow growth, whereas frontal and parietal regions developed more rapidly [40]. The slow early postnatal growth of the sensory and motor regions observed in this study might be explained by the initial, rapid maturation of these regions in the prenatal and early postnatal periods before the infants were scanned in the study [40]. The findings from this study also showed that, among subcortical regions, the hippocampus showed slower growth rates (82%–86%) compared with other structures, which had similar rates of volume increase (104%–107%), during the first year of life [40]. Neuroimaging data from another longitudinal study in developing children and young adults (age range: 3.5–33 years) have also shown that the brain cortex exhibits developmental trajectories of varying complexity; in general, poly-sensory and higher-order association areas of the cortex that have a complex laminar architecture exhibited complex developmental trajectories, whereas cortical regions with a simple laminar architecture, which included most limbic regions of the brain, showed simpler developmental trajectories [34]. A longitudinal paediatric neuroimaging study conducted in participants aged ~4–22 years showed nonlinear, region-specific changes in cortical grey matter volume, with an increase in preadolescence followed by a decrease in postadolescence [35]. The functional capacity of the brain does not necessarily advance uniformly with age [32]. A cross-sectional study conducted in participants aged 3–21 years revealed the complex nature of functional brain maturation [33]. The findings of this study indicated that brain connectivity patterns show dynamic changes through childhood and are dependent on the specific brain regions studied [33]. Moreover, functional brain developmental trajectories showed both linear and nonlinear patterns [33]. Functional network development of the amygdala, a brain region involved in processing emotional and social behaviour [41–43], showed a few nonlinear age-related connectivity changes in a cross-sectional study conducted in children from 3 months to 5 years of age [37]. Some studies suggest that the myelinated white matter of the brain, which is essential for efficient communication between various brain networks and higher-order function [44], may also exhibit nonlinear development during the first few years of life with distinct temporal patterns of development observed for specific white matter regions [45,46]. In a study where healthy infants underwent brain imaging at around 2 weeks, 1 year, and 2 years of age, a rapid change in white matter was observed during the first year followed by a slower maturation in the second year [46]. In another study, analysis of longitudinal white matter development in children between 2.5 months and 5.5 years of age showed that the myelin water fraction, a surrogate measure of myelin content, increased nonlinearly with age, with more rapid changes at early ages followed by slower development at older age [45]. The findings of this study also revealed that the most intense, fastest myelination rates occurred at earlier ages for core white matter and at a later time in the peripheral regions of the cortex [45]. Although substantial myelination and a rapid increase in white matter maturation occur during the first 2 years of life, the process continues and undergoes refinement through early childhood, adolescence, and adulthood, suggesting that microstructural changes in white matter are nonlinear in nature [47]. The myelination timing also varies across brain regions, with earlier development in the core sensory and motor regions and later development in the frontal and temporal connections [9,47]. Collectively, the above evidence of the nonlinear nature of structural and functional brain development may provide insights regarding the inherent nonlinear learning and developmental trajectories observed in children and might further support the need to incorporate nonlinear learning in ECCE.

Adopting nonlinear learning in early childhood education may offer various benefits. However, it should be noted that the evidence presented and the conclusions drawn are derived from studies of nonlinear learning in the context of physical education. By viewing the learner, environment, and educator as part of a dynamic and complex interacting system, nonlinear learning recognises the inherent complexities involved in the learning process [28]. This mutuality between the individual and the environment may provide opportunities for designing learning environments that can facilitate the development of various skill sets and capacities in the learners [28]. Some elements of nonlinear learning that could potentially be harnessed for education include exploration through variability, flexibility, creativity, and focus on the individual [27]. Nonlinear learning recognises the importance of introducing variability in the learning environment to promote exploratory behaviours in the learner [27,48]. In a nonlinear learning approach, the learning process is guided by applying task-specific constraints, environmental constraints, or personal constraints specific to each learner [26–28,48]. Adapting to these dynamic constraints could potentially lead to successful learning and may also foster independent, creative, and goal-directed behaviours in the process [26–28,48]. A nonlinear learning approach is learner-centred as it can offer a personalised learning experience; it accounts for individual differences (i.e. the inherent nonlinearities in learners); recognises the need for representative and facilitative types of learning for individual learners; and has the potential to accommodate learners with different abilities, varied learning styles, and prior knowledge [27,28,48,49]. Nonlinear learning supports the basic psychological needs of greater self-regulating autonomy, competency, and

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relatedness, which are important for promoting intrinsic motivation in learning [27,28,50]. It provides a multifaceted learning environment that may increase learners' motor proficiency, self-esteem, self-awareness, and critical and inventive thinking [27,48,51,52]. Holistic development emphasises the dynamic interactions and interplays between children and their multifaceted natural and social environments [24]. Nonlinear learning may occur optimally in such dynamic contexts in which the learner constantly interacts with their environment and thereby acquires knowledge [26–28,53].

The Role of Play in ECCE

Learning through play has been recognised as a central element and essential strategy of quality ECCE that brings together a child's various spheres of life such as the home, school, community, and the wider world [5,7,12,54–58]. Play is essential for optimal child development and provides a unique context for diverse and hands-on early learning experiences. Learning through play encourages the development of holistic skills across cognitive, physical, intellectual, social, and emotional domains [5,54–60]. Children learn optimally when they actively engage in practical activities and have a role in their learning experience [54,57,58]. Play is often spontaneous and voluntary and is driven by a child's initiative, intrinsic motivation, and self-choice [54,58]. An essential requirement of learning through play is that children should have agency over the experience and must be guided or supported rather than instructed or directed [57,58,61].

Play is essential for foundational motor development in children, which has lifelong benefits; play-based activities support the development of both fine and gross motor skills [54,55]. Play is associated with improvements in executive function, which facilitates the development of prolonged attention, filtering distractions, enhanced self-regulation and self-control, problem-solving, and mental flexibility [54]. During play, children need to focus on the task, balance their needs with those of their peers or social partners, and in the case of make-believe or pretend play, show self-regulation and inhibit distractions from their environment [54,57,61]. Results of a study conducted on preschool children found a positive correlation between executive function and pretense representations, suggesting that certain executive function skills may be implicated in pretend play, such as self-control, the ability to inhibit reality, and flexibility to manage conflicting mental representations [62]. Engaging in playful activities may facilitate associative fluency; preschool children who were allowed to play freely with objects named more nonstandard uses for each of those objects in an alternate-uses test compared with children who used the same objects in an imitative context or those who were not exposed to the objects [63]. Children may also engage in play to try and resolve ambiguity, test hypotheses, or understand causality [57,64–66]; for example, preschool children who viewed a demonstration of a toy where the cause and effect was unclear spent most of their time playing with the same, familiar toy, whereas children who viewed a demonstration that showed how the toy worked (i.e. cause and effect was clear) spent most of their time playing with a new toy [57,66]. Pretend play is important for subjective well-being and coping [67]. Specifically, the expression of affect in play was related to positive moods in daily life. Imagination and organisation during play were related to coping ability [67]. Play fosters language development in children; results of a study showed that distributing blocks for play was associated with higher language scores in children aged 1.5–2.5 years from middle- and low-income families [68].

Evidence from preclinical studies suggests that play is essential for healthy brain development [54,69–71]. Play refines the prefrontal cortex, a brain region involved in executive functioning skills [54,70,72–74]. Studies have reported play-associated neuroplasticity in the prefrontal cortex, suggesting that playful experiences may have a positive impact on the functionality of this brain region potentially leading to efficient information processing as well as behavioural flexibility [72–75]. These play-induced changes in the prefrontal cortex may also influence the regulation of other subcortical regions such as the amygdala, which is involved in processing emotions [41,42,70]. Play deprivation may be associated with anatomical changes in prefrontal cortical neurons and with an immature prefrontal cortex and could interfere with synaptogenesis and pruning [54,70,73]. Socially isolated, play-deprived rats were less competent at problem-solving during behavioural tasks, were found to be less socially active at a later stage, and showed impaired emotional regulation [54,70,71,76,77]. Play stimulated the transcription of brain-derived neurotropic factor, a protein involved in the growth of new neurons and synapses, in the rat amygdala and frontal cortex [54,78]. Play also activates a brain neurotransmitter called norepinephrine, which modulates synaptic learning and neuroplasticity [54,79].

Five distinguishing characteristics of play as a mode of learning have been identified (Figure 1), which might potentially contribute to children's ability to interpret and learn optimally from various experiences [57,58,61,69]. Learning through play that engages these characteristics could activate reward centres in the brain and stimulate neural networks that facilitate learning, memory, and cognition [69]. Preclinical studies suggest that play that is socially interactive can shape the prefrontal cortex and, thereby, influence executive functioning as well as refine the animal brain to be more adaptable later in life [69,70,73]. The importance of play-based learning at different human developmental stages from conception to 8 years of age is shown in Figure 2 [58].

Play fosters the development of various skills, such as multi-tasking, conflict resolution, divergent thinking, critical thinking, decision-making, organising thought into cause and effect, communication, collaboration, cooperation, sharing, negotiation, and self-advocacy [54,57–60,67]. Play is also a powerful medium for expressing imagination and curiosity and fostering creativity [54,58,60]. Active engagement and experimentation with the world through play might help children overcome fear, gain confidence and satisfaction, and build resilience [54,58–60].

Play provides a unique opportunity for children to form safe, stable, and affective relationships with their caregivers, which, in turn, is critical for optimal child learning and development [54,60,80]. Play enables caregivers to fully relate to and engage with the child while keeping the child's developmental age in mind [54,60]. When caregivers observe children during child-driven play, they learn to see the world from the child's perspective, identify their thinking

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Figure 1: The five distinguishing characteristics of play-based learning experiences [57,58,61].

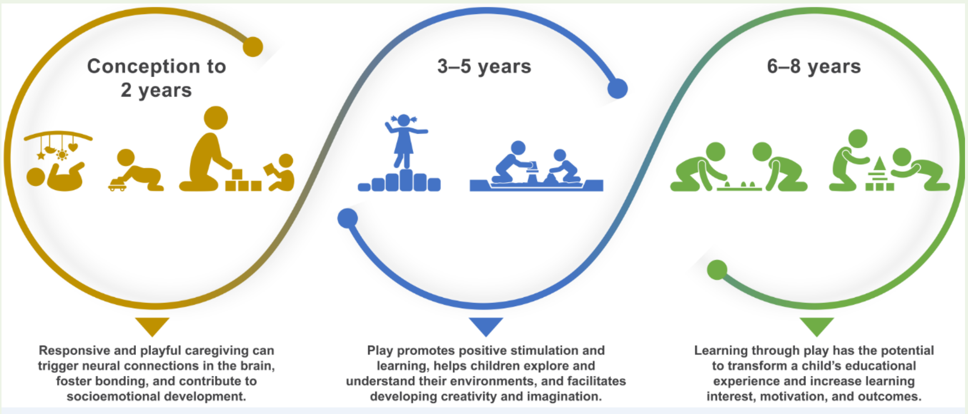

Figure 2: The benefits of play during the period from conception to 8 years of age [58].

styles, and understand themes of anger, guilt, shame, and hurt, which the child might otherwise suppress [54,60]. Pretend play helps children understand and build empathy in situations where they seek another person's perspective [81,82]. Children who are naturally less verbal can express themselves to adults through their play [60]. Active caregiver–child interactions during play build enduring and empathetic relationships, lead to better communication, and provide opportunities for more nurturing guidance [54,60].

Conclusions

The pace of brain development during the period from birth to 8 years is rapid compared to any other time in life. This early period in life is when the brain is naturally more receptive to diverse and enriching experiences. Early childhood thus presents a critical window of opportunity to provide high-quality, child-centred, flexible, multifaceted, and intrinsically motivating learning experiences. These experiences positively influence a child's overall developmental trajectory, holistic growth, and lifelong well-being. The evidence presented informs us that brain development itself is nonlinear and that nonlinear learning trajectories, unique learning styles, individual variability, and unpredictability are inherent characteristics of childhood learning and development. As stated earlier, early learning experiences are heavily influenced by several interacting factors in the child's environment. This calls for a need to

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adopt nonlinear learning interventions that could provide children with flexibility and agency to choose their learning trajectories and styles. An optimal way of providing enriching, hands-on, and deep early learning experiences and promoting holistic growth in children is by encouraging play during early childhood. Play is essential for optimal brain development and provides opportunities for responsive stimulation and nurturing guidance. We conclude that learning interventions that acknowledge nonlinearity and the importance of play in early childhood are likely to be beneficial and effective in the context of ECCE and for the development of relevant twenty-first-century skills and competencies for lifelong learning and success.

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References

1. Center on the Developing Child at Harvard University (2020) InBrief: The Science of Early Childhood Development.
2. Immordino-Yang MH, Darling-Hammond L, Krone CR (2019) Nurturing nature: How brain development is inherently social and emotional, and what this means for education. Educ Psychol 54: 185-204.
3. Center on the Developing Child at Harvard University (2020) The Science of Early Childhood Development: Closing the Gap Between What We Know and What We Do.
4. Transforming the Workforce for Children Birth Through Age 8: A Unifying Foundation. Washington (DC): Committee on the Science of Children Birth to Age 8: Deepening and Broadening the Foundation for Success; Board on Children, Youth, and Families; Institute of Medicine; National Research Council..
5. UNICEF (2017) Early Moments Matter for Every Child.
6. UNICEF (2022) Early Childhood Development.
7. Ministry of Education, Government of India (2022) National Curriculum Framework for Foundational Stage 2022.
8. Johnson MH (2001) Functional brain development in humans. Nat Rev Neurosci 2: 475-483.
9. Tierney AL, Nelson CA (2009) Brain development and the role of experience in the early years. ZeroThree 30: 9-13.
10. American Psychological Association (2018) APA Dictionary of Psychology: Piagetian Theory.
11. Tuddenham RD (1966) Jean Piaget and the world of the child. Am Psychol 21: 207-217.
12. Ministry of Women & Child Development, Government of India (n.d.) National Early Childhood Care and Education (ECCE) Curriculum Framework.
13. UNESCO (2016) Global Education Monitoring Report: Education for People and Planet – Creating Sustainable Futures for All.
14. Black MM, Walker SP, Fernald LCH, Andersen CT, DiGirolamo AM et al. (2017) Early childhood development coming of age: Science through the life course. Lancet 389: 77-90.
15. Britto PR, Lye SJ, Proulx K, Yousafzai AK, Matthews SG, et al. (2017) Nurturing care: Promoting early childhood development. Lancet 389: 91-102.
16. Engle PL, Fernald LCH, Alderman H, Behrman J, O'Gara C, et al. (2011) Strategies for reducing inequalities and improving developmental outcomes for young children in low-income and middle-income countries. Lancet 378: 1339-1353.
17. UNICEF (2023) Home Environment.
18. Bornstein MH, Leventhal T (2015) Children in bioecological landscapes of development. Hand book of child psychology and developmental science. (7thed), John Wiley & Sons, Inc.
19. Berlinski S, Galiani S, Gertler P (2009) The effect of pre-primary education on primary school performance. J Public Econ 93: 219-234.
20. UNICEF (2023) Early Childhood Education.
21. Center on the Developing Child at Harvard University (2017) Neglect.
22. Ministry of Education, Government of India (2020) National Education Policy.
23. Reilly DH (2000) Linear or nonlinear? a metacognitive analysis of educational assumptions and reform efforts. Int J Educ Manag 14: 7-15.
24. Kim M, Sankey D (2010) The dynamics of emergent self-organisation: Reconceptualising child development in teacher education. Aust J Teach Educ 35: 79-98.
25. Trygestad J (1997) Chaos in the Classroom: An Application of Chaos Theory.
26. Chow JY, Davids K, Hristovski R, Araújo D, Passos P (2011) Nonlinear pedagogy: Learning design for self-organizing neurobiological systems. New Ideas Psychol 29: 189-200.
27. Chow JY (2013) Nonlinear learning underpinning pedagogy: Evidence, challenges, and implications. Quest 65: 469-484.
28. Chow JY, Davids K, Renshaw I, Rudd J (2020) Nonlinear Pedagogy. Encyclopedia of Educational Innovation. Springer.
29. Casey BJ, Tottenham N, Liston C, Durston S (2005) Imaging the developing brain: What have we learned about cognitive development? Trends Cogn Sci 9: 104-110.
30. Gogtay N, Giedd JN, Lusk L, Hayashi KM, Greenstein D, et al. (2004) Dynamic mapping of human cortical development during childhood through early adulthood. Proc Natl Acad Sci U S A 101: 8174-8179.
31. Kolk SM, Rakic P (2022) Development of prefrontal cortex. Neuro-psychopharmacology 47: 41-57.
32. Sinnamon GCB (2019) The pathological consequences of exposure to domestic and family violence in childhood. In Child Abuse and Neglect: Forensic Issues in Evidence, Impact, and Management. Elsevier Academic Press. Pp: 175-202.
33. Faghiri A, Stephen JM, Wang YP, Wilson TW, Calhoun VD (2019) Brain development includes linear and multiple nonlinear trajectories: A cross-sectional resting-state functional magnetic resonance imaging study. Brain Connect 9: 777-788.
34. Shaw P, Kabani NJ, Lerch JP, Eckstrand K, Lenroot R, et al. (2008) Neurodevelopmental trajectories of the human cerebral cortex. J Neurosci 28: 3586-3594.
35. Giedd JN, Blumenthal J, Jeffries NO, Castellanos FX, Liu H, et al. (1999) Brain development during childhood and adolescence: A longitudinal MRI study. Nat Neurosci 2: 861-863.
36. Wierenga LM, Langen M, Oranje B, Durston S (2014) Unique developmental trajectories of cortical thickness and surface area. Neuroimage 87: 120-126.
37. Gabard-Durnam LJ, O'Muircheartaigh J, Dirks H, Dean DC, Tottenham N, et al. (2018) Human amygdala functional network development: A cross-sectional study from 3 months to 5 years of age. Dev Cogn Neurosci 34: 63-74.
38. Thatcher RW (1992) Cyclic cortical reorganization during early childhood. Brain Cogn 20: 24-50.
39. Thatcher RW, Walker RA, Giudice S (1987) Human cerebral hemispheres develop at different rates and ages. Science 236:1110-1113.
40. Gilmore JH, Shi F, Woolson SL, Knickmeyer RC, Short SJ, et al. (2012) Longitudinal development of cortical and subcortical gray matter from birth to 2 years. Cereb Cortex 22: 2478-2485.

Citation: Gowda VK, Ravi Kumar CP, Goyal R, Sidhwani S. Childhood Development, Learning, and Education: A Focus on Nonlinear Learning and Play. Indian J Neurol. 2024;5(1): 129.

41. Phelps EA, LeDoux JE (2005) Contributions of the amygdala to emotion processing: From animal models to human behavior. Neuron 48: 175-187.

42. Baxter MG, Croxson PL (2012) Facing the role of the amygdala in emotional information processing. Proc Natl Acad Sci U S A 109: 21180-21181.

43. Adolphs R (2010) What does the amygdala contribute to social cognition? Ann N Y Acad Sci 1191: 42-61.

44. Fields RD (2008) White matter in learning, cognition and psychiatric disorders. Trends Neurosci 31: 361-370.

45. Dean DC 3rd, O'Muircheartaigh J, Dirks H, Waskiewicz N, Walker L, et al. (2015) Characterizing longitudinal white matter development during early childhood. Brain Struct Funct 220: 1921-1933.

46. Sadeghi N, Prastawa M, Fletcher PT, Wolff J, Gilmore JH, et al. (2013) Regional characterization of longitudinal DT-MRI to study white matter maturation of the early developing brain. Neuroimage 68: 236-247.

47. Lebel C, Deoni S (2018) The development of brain white matter microstructure. Neuroimage 182: 207-218.

48. Mohammadi Orangi B, Yaali R, Ackah-Jnr FR, Bahram A, Ghadiri F (2021) The effect of nonlinear and linear methods and inclusive education on self-esteem and motor proficiency of ordinary and overactive children. J Rehabil Sci Res 8: 69-78.

49. Robberecht R (2007) Interactive nonlinear learning environments. Electron J E-Learn 5: 59-68.

50. Deci EL, Ryan RM (2000) The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. Psychol Inq 11: 227-268.

51. Moy B, Renshaw I, Davids K (2016) The impact of nonlinear pedagogy on physical education teacher education students' intrinsic motivation. Phys Educ Sport Pedagogy. 21: 517-538.

52. Lee MCY, Chow JY, Button C, Tan CWK (2017) Nonlinear pedagogy and its role in encouraging twenty-first century competencies through physical education: A Singapore experience. Asia Pac J Educ 37: 483–499.

53. Barab SA, Kirshner D (2001) Guest editors' introduction: Rethinking methodology in the learning sciences. J Learn Sci 10: 5-15.

54. Yogman M, Garner A, Hutchinson J, Hirsh-Pasek K, Golinkoff RM, et al. (2018) The power of play: A pediatric role in enhancing development in young children. Pediatrics 142: e20182058.

55. Lunga P, Esterhuizen S, Koen M (2022) Play-based pedagogy: An approach to advance young children's holistic development. South African Journal of Childhood Education 12: a1133.

56. Nilsson M, Ferholt B, Lecusay R (2018) The playing-exploring child': Reconceptualizing the relationship between play and learning in early childhood education. Contemp 19: 231-245.

57. Zosh J, Hopkins E, Jensen H, Liu C, Neale D, Hirsh-Pasek K, et al. (2017) Learning through play: A review of the evidence [White paper]. The LEGO Foundation, DK.

58. The LEGO Foundation in support of UNICEF (2018) Learning through play: Strengthening learning through play in early childhood education programs.

59. Nijhof SL, Vinkers CH, van Geelen SM, Duijff SN, Achterberg EJM, et al. (2018) Healthy play, better coping: The importance of play for the development of children in health and disease. Neurosci Bio behav Rev 95: 421-429.

60. Ginsburg KR; American Academy of Pediatrics Committee on Communications; American Academy of Pediatrics Committee on Psychosocial Aspects of Child and Family Health (2007) The importance of play in promoting healthy child development and maintaining strong parent–child bonds. Pediatrics 119:182-191.

61. Zosh JM, Hirsh-Pasek K, Hopkins EJ, Jensen H, Liu C, et al. (2018) Accessing the inaccessible: Redefining play as a spectrum. Front Psychol 9: 1124.

62. Carlson SM, White RE, Davis-Unger A (2014) Evidence for a relation between executive function and pretense representation in preschool children. Cogn Dev 29: 1-16.

63. Dansky JL, Silverman IW (1973) Effects of play on associative fluency in preschool-aged children. Dev Psychol 9: 38-43.

64. Cook C, Goodman ND, Schulz LE (2011) Where science starts: Spontaneous experiments in preschoolers' exploratory play. Cogn 120: 341-349.

65. Buchsbaum D, Bridgers S, Skolnick Weisberg D, Gopnik A (2012) The power of possibility: Causal learning, counterfactual reasoning, and pretend play. Philos Trans R Soc Lond B Biol Sci 367: 2202-2212.

66. Schulz LE, Bonawitz EB (2007) Serious fun: Preschoolers engage in more exploratory play when evidence is confounded. Dev Psychol 43:1045-1050.

67. Fiorelli JA, Russ SW (2012) Pretend play, coping, and subjective well-being in children: A follow-up study. Am J Play 5: 81-103.

68. Christakis DA, Zimmerman FJ, Garrison MM (2007) Effect of block play on language acquisition and attention in toddlers: A pilot randomized controlled trial. Arch Pediatr Adolesc Med. 161: 967-971.

69. Liu C, Solis L, Jensen H, Hopkins E, Neale D,et al. (2017) Neuroscience and learning through play: A review of the evidence (research summary). The LEGO Foundation.

70. Pellis SM, Pellis VC, Himmler BT (2014) How play makes for a more adaptable brain: A comparative and neural perspective. Am J Play 7:73-98.

71. Pellis SM, Pellis VC (2007) Rough-and-tumble play and the development of the social brain. Curr Dir Psychol Sci 16: 95-98.

72. Siviy SM (2016) A brain motivated to play: Insights into the neurobiology of playfulness. Behaviour 153:819-844.

73. Bell HC, Pellis SM, Kolb B (2010) Juvenile peer play experience and the development of the orbitofrontal and medial prefrontal cortices. Behav Brain Res 207: 7-13.

74. Himmler BT, Pellis SM, Kolb B (2013) Juvenile play experience primes neurons in the medial prefrontal cortex to be more responsive to later experiences. Neurosci Lett 556: 42-45.

75. Baarendse PJJ, Counotte DS, O'Donnel IP, Vanderschuren LJMJ (2013) Early social experience is critical for the development of cognitive control and dopamine modulation of prefrontal cortex function. Neuropsychopharmacology 38: 1485-1494.

76. Von Frijtag JC, Schot M, van den Bos R, Spruijt BM (2002) Individual housing during the play period results in changed responses to and consequences of a psychosocial stress situation in rats. Dev Psychobiol 41: 58-69.

77. Hol T, Van den Berg CL, Van Ree JM, Spruijt BM (1999) Isolation during the play period in infancy decreases adult social interactions in rats. Behav Brain Res 100: 91-97.

78. Gordon NS, Burke S, Akil H, Watson SJ, Panksepp J (2003) Socially induced brain "fertilization": Play promotes brain derived neurotrophic factor transcription in the amygdala and dorsolateral frontal cortex in juvenile rats. Neurosci Lett 341: 17-20.

79. Wang S, Aamodt S (2012) Play, stress, and the learning brain. Cerebrum 2012: 12.

80. Tamis-LeMonda CS, Shannon JD, Cabrera NJ, Lamb ME (2004) Fathers and Mothers at Play With Their 2- and 3-Year-Olds: Contributions to Language and Cognitive Development. Child Dev 75: 1806-1820.

81. Brown MM, Thibodeau RB, Pierucci JM, Gilpin AT (2017) Supporting the development of empathy: The role of theory of mind and fantasy orientation. Soc Dev 26: 951-964.

82. Hashmi S, Vanderwert RE, Price HA, Gerson SA (2020) Exploring the benefits of doll play through neuroscience. Front Hum Neurosci 14: 560176.

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