COGNITIVE FUNCTION FOR CHILDREN'S EDUCATION DEVELOPMENT

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Abstract

Understanding children's cognitive development lays the foundation for child education. The recent advancement in cognitive development challenges some of the conventional views of how children learn and how they succeed in school. This article highlights the contributions of cognitive development research to child education in three areas. The first area focuses on domain-specific developmental mechanisms for learning including theory theory and probabilistic learning model, theory of mind, testimony, and conceptual change. The second area is the domain-general developmental mechanisms focusing on self-regulation and executive function, as well as their relation to school readiness and success. Although pretense is arguably associated with both domain-general and domain-specific development, its relation with self-regulation is highlighted. The last area discusses children's learning process itself and the elaborate relation between learning and development.

Keywords: Cognitive Function, Children's Education Development.

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Introduction

Recent advances in research on executive function processes have important implications for understanding how children learn and why so many fail to perform at the level of their potential. This cutting edge volume brings together leading scientists and practitioners from education, neuroscience, and psychology to review the growing body of ideas and findings in this area. Emphasizes the importance of creating strategic classrooms that address executive function processes systematically in the context of a standards-based curriculum. Throughout, major questions and controversies in the field are addressed, and key directions for future investigation are identified. Bridging the gap between research and educational practice. On the one hand, the recent advancement in cognitive development challenges some of the conventional views of how children learn and how they succeed in school; on the other hand, it also provides theoretical underpinning and empirical support for some of the well-recognized ideologies and practices in early education.

Theory Domain for Learning

Children's learning mechanism is a topic deeply embedded in the debate of nature vs nurture. Nativists view learning as unfolding of innate, modulelike structures when triggered by environmental stimuli, while empiricists deny the very existence of abstract, coherent structures and see learning as building associations among information that is context dependent. Rooted in Piaget's constructivism, developmental 'theory theorists' have suggested that the way children learn resembles the process of scientific theory formation (e.g., Gopnik and Meltzoff, 1997). The recent development of the theory theory (Gopnik, 2012) attempts to consolidate the nativists' and the empiricists' views of the mechanism of children's learning by applying probabilistic learning model based on Bayesian statistics. Bayesian statistics conceive that the truth or falsity of propositions is uncertain and the evidence of the true state of the world is expressed as degrees of belief. Statements concerning the causal structures are considered as hypotheses. Prior probability of a hypothesis is specified, and then constantly updated in the light of new data. The probabilistic learning account proposes that young children, even infants, can infer causal structure from statistical information. Structures of the real world can be represented mathematically by generative models that allow the learner to compute the patterns of evidence generated by the structure and make inferences. The learner can also invert that process and learn about the structure of the real world from evidence. What is unique about the probability model is that it helps the learner to pick out the most likely hypothesis among all the hypotheses that are compatible with the pattern of evidence based on probability. Consequently, children are not constrained by the innately determined representations, nor do they start from a blank slate; instead, they are constantly assessing their data and testing hypotheses as scientists do. Learning becomes a process of integrating prior knowledge and new evidence to revise the representations of the world based on experience. In a recent review, Gopnik and Wellman (2012) provided empirical evidence that children from 16 months to 4 years of age adopt the probabilistic learning mechanisms such as informal experimentation through play, imitation, and informal pedagogy in their physical and psychological causal inferences.

One of the most appealing implications of the probabilistic learning account for educators is that it advocates explorative play as informal experimentation to generate causally relevant and informative evidence for children to make causal inferences. Gopnik and Wellman (2012: p. 1095) call this type of learning as 'learning from interventions.' They argued that by intervening first hand, one could rapidly narrow down the number of possible hypotheses in order to search more efficiently. These interventions need not to be systematically controlled experiments. Play, as informal experimentation, is sufficiently systematic to help children actively seek out evidence and discover causal structure. In the education sector, play has long been held as the driving force for learning during early childhood. The probabilistic learning account provides the theoretical underpinning from cognitive development perspective for the play-based learning viewpoint for the first time. Furthermore, this account also backs up the inquiry-based scientific education in general.

Theory of Mind

Children not only learn from firsthand exploration, they also learn new causal relations by observing others' interventions and through imitation. Gopnik and Wellman (2012) argued that the theory formation mechanism of children's learning not only applies to the causal structure of the world, but also the mind of the person teaching them. Indeed, teaching and learning are enterprises involving a theory of mind, the intuitive understanding of one's own and other people's mental states and activities, such as thoughts, beliefs, perceptions, knowledge, intentions, desires, and emotions, and of behavioral consequences of such mental states. A significant developmental milestone during early years of life, the awareness of people's mental life, and its relationship with behavioral outcome, is being proposed to be critical for learning and being taught more generally (Wellman and Lagattuta, 2004).

Recognizing existing differences and changes in knowledge is a theory of mind reasoning skill that is essential in teaching and learning. Young children will not yet be able to assume an intentional stance in learning until they see the possibility of acquiring knowledge. Research on the relationship between theory of mind and teaching and learning (e.g., Frye and Ziv, 2005; Wang, 2010) had shown that young children were sensitive to both the epistemic and motivational mental states in teaching and learning, such as the differences and changes in knowledge state, beliefs about knowledge state, and teaching and learning intentions. Furthermore, children's understanding of teaching and learning developed with their evolving theory of mind. Those who acquired false belief understanding also had a grasp of more sophisticated teaching and learning concepts such as imitation, embedded teaching, and discovery learning. In contrast, younger children who were yet to understand the independent nature of reality and mental representation failed to recognize that the teaching intention embedded in play, and treat pure discovery through coincidence as intentional learning. It seems that young children have mistaken 'learning by doing' as 'learning is doing.'

This line of research has several implications for early education. Firstly, it brought the precursors of metacognition during early childhood to light. Theory of mind enables children to think reflectively on their learning. Along with the developing executive functioning and self-regulation around the same time in life, which is discussed later in this article, these developmental achievements prepare children to become conscious learners with the capacity to actively monitor and regulate their own learning. Secondly, this line of research echoes Vygotsky's idea of social learning. Children learn in a network of knowledge exchange. In addition to firsthand intervention, social interactions between teachers and learners and among learners provide the much needed intentional teaching and learning such as demonstration, instruction, and guided discovery. Last but not least, young children's confusion between doing and learning suggests that effective teaching and learning have to be effortful, with sustained attention control, and working memory resources. Children can be busy all the time with hands-on activities and experiments in classroom. But only when children are mentally engaged in the tasks will they actually start to learn. In order to mentally engage children, teachers need to make the teaching intention and the knowledge state change explicit for them to take full advantage of the teaching event (Frye and Wang, 2008).

Testimony

Harris (2002) calls the top-down learning processes as learning from 'testimony.' Children rely extensively on adults' testimony to learn, especially about entities that are not readily observable, such as metaphysical entities like God and tooth fairy, as well as scientific entities like germs and the shape of the Earth. Sobel (2010) argued that probabilistic learning account is an integration of both bottom-up processes, such as extracting knowledge from observed data, and top-down processes, such as direct instruction. The degree to which children commit to these entities varies according to the exposure they receive about them. More generally, Sobel suggested that children learn causal structures simply by being told. Nevertheless, children do not readily trust everything they are told; instead, they selectively trust particular informants' testimony from an early age. By observing the informants at work, children constantly access the informants' motive, reliability, competence, and knowledgeability when learning; they also compare testimony with their own observation and make sensible choices (e.g., Clément, 2010; Liu et al., 2013). Testimony research highlights the role of direct instruction, which is compatible with the probabilistic learning account. Gopnik (2012) cautioned the use of direct instruction in teaching by emphasizing a balanced view of pedagogy. On the one hand, children know when they are being taught, which enables them to learn faster and more efficiently. On the other hand, explicit teaching limits the range of possible hypotheses for children to consider. A balanced view should consider direct instruction as one of the tools for teaching, yet at the same time provide examples, anomalies, encourage exploration and experimentation, and ask for explanations. Exploration and experimentation should be supported with appropriate scaffolding.

Conceptual Change

Another contribution of theory theory to child education is conceptual change (Vosniadou et al., 2008). Scientific theories develop in the context of paradigms (Kuhn, 1962), which refer to webs of shared concepts, beliefs, and practices, in the science community. The scientific theory change is not cumulative but revolutionary: old paradigms are rejected and replaced by new ones. The radical changes between theories make it difficult to establish rationally that one is better than another. Theory theory compares the process of children's cognitive development to that of theory development in the science community. Knowledge is acquired in domain-specific, theorylike structures. Conceptual change involves significant changes in concepts and theoretical frameworks. In the process of conceptual change, prior knowledge or misconceptions become stepping-stones toward more accurate knowledge and scientific explanations, although they may coexist with accurate ideas in the explanation and prediction. An individual's understanding can vary across contexts and domains, and there is not necessarily always linear improvement across age.

Conceptual change posits a relatively coherent body of domain-specific knowledge characterized by a distinct ontology and a causality that can give rise to explanation and prediction. Children have a rich set of ideas, conceptual frameworks, and reasoning skills. Organized into different domains, their naive theories explain and predict how things ought to behave, and solve problems. Conceptual change can be either bottom-up or top-down. Some misconceptions will self-correct without instruction as children gain more experience, such as one will not grow into a giant if eat more. These types of conceptual change are conservative and additive, largely unconscious. Yet some aspects of modern scientific knowledge are so counterintuitive that children are unlikely to achieve understanding without instruction, such as germs, particles, and the shape of the Earth. The instruction-induced conceptual changes are usually radical and deliberate. The process involves hypothesis testing, analogy, and metarepresentation, sometime thought experiments.

Rather than simple accumulation of information, proficiency in science is theory building based on prior knowledge and misconceptions. Factual knowledge must be placed in a conceptual framework to be well understood. Children need to learn how concepts are related to each other and their implications and applications. For spontaneous conceptual change, teachers need to provide an enriched environment for children's explorations and scaffold scientific thinking by positing task-appropriate questions at the right moment. For instruction-induced conceptual change, it is important to confront children with conflicts in their framework. Teachers need to focus on a few key concepts and core ideas and explain causality.

Domain Developmental for Learning

Self-Regulation and Executive Function

If theory theory is a domain-specific learning mechanism, self-regulation is rather a broad construct that lays the foundation for development across all domains. Self-regulation is an integrated, multidimensional construct that incorporates a broad range of psychological processes including biological processes, attention, emotion, behavior, and cognition. As a goal-directed behavior over time and in varying contexts, self-regulation generally entails three aspects: representing goals, motivation to achieve goals, and capacity to achieve goals despite of obstacles. Executive function is a construct subserving self-regulation that is discussed mainly by cognitive psychologists. It encompasses several distinctive cognitive constructs, including working memory, mental set shifting, and inhibitory control (Hofmann et al., 2012). While the measures for self-regulation can be both teacher or parent reports or behavior tasks such as delay of gratification, executive function measures are mainly behavioral tasks for children, including working memory tasks, stroop-type tasks for measuring inhibitory control, and set shifting tasks such as the Dimensional Change Card Sort (DCCS) task (Zelazo et al., 2003).

School Readiness and Success

While the focus of school readiness has traditionally been on academic preparedness, more recently it has been recognized as a multidimensional construct that includes cognitive and social emotional competences such as self-regulation (Blair, 2002) and theory of mind (Astington and Pelletier, 2005). The very components of self-regulation such as attention, inhibitory control, planning, abiding by rules, and working memory can explain why children's ability to self-regulate is strongly related to their performance in school. Virtually any effortful academic task requires attention control ability including focused attention, and suppression of interference or conflict from other, irrelevant information, which improves significantly during the early school years. Blair (2002) proposed that inefficient emotional regulation inhibits the use of higher order cognitive regulation, therefore affects academic achievement. Behavioral regulation supports the development of internally driven conduct norms like sitting quietly in the classroom, which children need in order to function independently in the school. Cognitive regulation measured by executive function tasks not only enables children to hold multiple stimuli and/or perspectives in mind and switch between two incompatible classification rules flexibly, it also moderately correlates and predicts later theory of mind development (Devine and Hughes, in press) that in turn affects children's learning.

Both correlational and longitudinal data have demonstrated the connection between self-regulation and academic success. A recent meta-analysis (Allan et al., 2013) found a modest overall relation between self-regulation and the academic skills of preschool and kindergarten children. Consistent with the distinction between the cognitive-laden cool self-regulation and the affect-laden hot self-regulation, academic skills were found to be more associated with measures of cool self-regulation than with those of hot self-regulation. Both behavior tasks and teacher reports were related to academic skills. Furthermore, self-regulation in general was more strongly associated with early math skills than with early literacy skills. Longitudinal data showed that self-regulation abilities strongly predicted later success in school and life. Self-regulation measured in preschool predicted children's academic success in the early primary years, even when variations in their intelligence or family backgrounds were controlled (e.g., Blair and Razza, 2007).

Class activities that demand higher levels of executive control might mask young children's mastery of the academic skills that the activities aim to assess. Evidence from adult literature suggests that 'depleted' self-control subsequently lowered one's cognitive function (Baumeister et al., 2007). Knowing this challenge children face in learning, teachers ought to consider the general cognitive demands of a lesson in addition to its content-specific requirements in lesson planning. There is also evidence that attention control skill is trainable for children as young as 4-6 years of age using computer games (Rueda et al., 2005) that might suggest an alternative pathway for academic enhancement of general executive function training.

Pretense

The cognitive flexibility required for self-regulation and executive function is readily available in children's pretend play. Assuming a pretend character in play helps children to take on another perspective. Even more so, when the child steps out from the play frame to plan, coordinate, and negotiate roles and play scenarios, she attends to other players' perspective while assuming her own identity. In the process of back and forth shifting of perspectives, children practice executive control skills related to inhibiting the reality, holding multiple perspectives at the same time, and switching from one perspective to another flexibly. Carlson and associates (cf Carlson and White, 2013) found children's pretend play was indeed related to executive function measured by DCCS, controlling for working memory and verbal ability.

Carlson and White (2013) brought attention to the psychological distancing effect of symbolic thought. They argued that substituting direct experiences with symbols distances one from the sought after 'hot' reward in the delay of gratification tasks, which allows behavior to be controlled in light of the symbol rather than the stimulus itself. In the Less is More task, children need to indicate that they want the tray with less treats to actually get the tray with more treats. Young children found it rather difficult to resist the temptation of wanting the tray with more treats. When symbols were used to represent the real treats, however, young children's performance significantly improved. Attention control strategies such as the generalization from the symbolic representation to the real stimuli help children to manage the delay more efficiently.

Pretend play and symbolic representation and reasoning carry a lot of weight in early childhood education. The idea that these intuitive teaching practices actually support higher order executive function is reassuring and encouraging. A study by Bodrova and Leong (2007) had found that teacher-supported socio-dramatic play was an effective strategy for developing preschool children's self-regulation. More research is needed to fully understand the link between good teaching practices and children's cognitive development.

Pretense is believed to facilitate theory of mind development due to its metarepresentational nature (Leslie, 1987). Rich in counterfactual reasoning, it is also essential to probabilistic model learning (Walker and Gopnik, 2013). However, a recent comprehensive review (Lillard et al., 2013) found that the empirical evidence on the impact of pretend play on children's cognitive and social development was inconclusive. More rigorous research is needed to fully understand how pretend play facilitates learning. Meanwhile, play-based learning, according to Lillard et al., is still the most positive means yet known for child development.

How Do Children Learn?

So far the article has been focusing on the developmental mechanisms for learning. How about the learning process itself? How do children really learn? According to Siegler (2000), research on children's learning has reemerged after the decline of associationism focusing on learning of meaningful concepts and skills that are important in children's lives. One of the leading theories on children's learning is the over-lapping waves theory (Siegler, 1996, 2000, 2005) that centers on the variety of strategies and ways of thinking in learning and problem solving. According to this theory, multiple approaches coexist simultaneously, with new strategies being added and old strategies cease to function sometimes, and certain single strategy could exist for a prolonged period of time, even after more advanced strategies emerge. It emphasizes cognitive diversity in learning, both with individuals and across them, even within an individual solving the same problem in different trials or within the same trial. A schematic depiction of the overlapping waves model, outlines the diversity of learning strategies in terms of the levels of sophistication, the timing, and the complex relationships among the strategies.

To study the detailed learning process with ecological validly, microgenetic methods of learning are adopted in the overlapping waves theory. These methods make dense observations in relation to the rate of change over a period of rapidly changing competence and intense analysis of these observations. The richness of the microgenetic data allows the over-lapping waves theory to analyze learning along five dimensions, the path, rate, breadth, source, and variability of learning.

One of the major contributions of the overlapping waves theory is that it marries learning and development. Siegler argues that the learning and development processes have a lot in common in terms of variability, choice, and change, there-fore cannot be distinguished from one and another. Some of the learning analyses echo the age-related changes described by developmentalists like Piaget. Siegler calls his theory as a developmental approach to learning that integrates both qualitative and quantitative changes. The educational implication of microgenetic analysis of learning is that it provides evidence for how teaching instruction unfolds children's learning therefore is helpful for designing more effective future instructions.

Conclusions

The learning process is inseparable from child development. Learning is a process of hypothesis testing based on probabilistic models. Children learn through play, observation, and through explicit teaching, during which children are constantly testing and adjusting their hypotheses based on data collected from spontaneous experimentation, observation of other people's intervention, as well as knowledge and intentional attribution in teaching. The domain-general cognitive abilities of self-regulation and executive function help children succeed in school by setting learning goals, focusing their attention on the learning tasks at hand, resisting temptations, and regulating their emotions. Children's learning strategies show great variability, both within and across individuals. Teaching and learning are goal-directed, mindful, and effortful enterprises. Education should provide children with opportunities of supported exploration and experimentation, intentional demonstration and instruction, as well as guided discovery. a) Learning in young children is socially mediated. Families, peers and teachers are all important. Even basic perceptual learning mechanisms such as statistical learning require social interaction to be effective. This limits educational approaches such as e-learning in the early years. b) Learning by the brain depends on the development of multi-sensory networks of neurons distributed across the entire brain. For example, a concept in science may depend on neurons being simultaneously active in visual, spatial, memory, deductive and kinaesthetic regions, in both brain hemispheres. c) Children construct explanatory systems to understand their experiences in the biological, physical and psychological realms. These are causal frameworks, for example to explain why other people behave as they are observed to do, or why objects or events follow observed patterns. Knowledge gained through active experience, language, pretend play and teaching are all important for the development of children's causal explanatory systems. Children's causal biases should be recognised and built upon in primary education. d) Children think and reason largely in the same ways as adults. However, they lack experience, and they are still developing important metacognitive and executive function abilities. Learning in classrooms can be enhanced if children are given diverse experiences and are helped to develop self-reflective and self-regulatory skills. e) Language is crucial for development. The ways in which teachers talk to children can influence learning, memory, understanding and the motivation to learn. There are also enormous individual differences in language skills between children in the early years. f) Incremental experience is crucial for learning and knowledge construction. The brain learns the statistical structure of 'the input'. It can be important for teachers to assess how much 'input' a child's brain is actually getting when individual differences appear in learning. Differential exposure (for example to spoken or written language) will lead to differential learning. As an example, one of the most important determinants of reading fluency is how much text the child actually reads, including outside the classroom. g) Thinking, reasoning and understanding can be enhanced by imaginative or pretend play contexts. However, scaffolding by the teacher is required if these are to be effective. Individual differences in the ability to benefit from instruction and individual differences between children are large in the primary years, hence any class of children must be treated as individuals.

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