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Children's Language Learning from an Embodied Cognition Perspective: Opportunities, Challenges, and Future Directions

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Abstract: The emergence of embodied cognition theory has altered our traditional understanding of children's language learning, emphasizing the close connection between the body, environment, and movement. This paper discusses the opportunities, challenges, and future directions of research on children's language learning from the perspective of embodied cognition. It concludes that multisensory engagement can greatly improve children's comprehension and memorization of language knowledge and that language acquisition is intimately tied to bodily perception, movement, and emotional experience. In addition, children's language acquisition can also be effectively aided by embodied cognition techniques as multimedia aids, gesture and enactment, and imagery. Based on previous evidence, we propose an integrated language learning framework and a new relevance-integration taxonomy for children's language learning from the perspectives of embodied cognition and cognitive load theories. In order to support the long-term growth of children's language education, future research should focus more on the requirement of embodied language learning in the preschool-primary transition and optimize the teaching objectives and contents.

Keywords: Embodied cognition; Language education; Children; Learning; Actions

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1. Introduction

The rise of embodied cognition theory in cognitive research offers a fresh perspective on the investigation of young language learners. It challenges the disembodied perspective of conventional cognitive research, which divides the mind from the body, by highlighting the dynamic interaction of the body, environment, and behavior in cognition. Embodied cognition theory has transformed our understanding of children's language acquisition, revealing it as a holistic process deeply intertwined with movement, bodily perception, and emotional experience, not merely abstract symbol processing.

Children's language learning, as an important part of cognitive development, has been receiving attention

from educators and researchers. Traditional language education models focus on the transmission of linguistic knowledge and disembodied skill training, but with the deepening of embodied cognition theory, we realize that children's language learning is not just an autonomous brain computational process, but is tightly linked to bodily experiences, environmental interactions, and action practices. For example, when children acquire vocabulary that describes actions, it is often accompanied by corresponding body movements, and this kind of action involvement not only helps vocabulary comprehension but also enhances memorization. Children are able to utilize the language they have acquired more naturally in situational simulations or role-playing exercises, which implies that physical involvement and environment creation have a positive effect on language learning.

In addition to offering a theoretical foundation and useful advice for the development of innovative children's language education models and the improvement of educational effects, the theory of embodied cognition offers a distinctive viewpoint that allows us to reexamine how children learn languages. It also encourages us to investigate the nature and process of language learning from a variety of perspectives, including the body, environment, and actions. This paper aims to provide practical inspiration and a point of reference for the theory and practice of children's language education by examining the features, realizations, and influencing factors of children's language learning from the standpoint of embodied cognition.

2. Definition and core of embodied cognition theory

Embodied cognition theory, as the core paradigm of second-generation cognitive science, subverts the disembodied view of traditional cognitive science, which separates the mind from the body, and emphasizes that cognitive activities are generated in the dynamic process of interaction between the body, environment, and behavior. Barsalou [1] pointed out that modal simulations, bodily states, and situated action underlie cognition. Cognitive content is anchored in specific contexts through the interaction between the body and the environment. For example, the brain's corresponding motor cortex area is activated in addition to the language area when someone reads verbs that convey actions, such as grasp, kick, etc. Additionally, the interaction of brain systems demonstrates how embodied simulation is necessary for language understanding, indicating that children's reading comprehension could be considerably enhanced by physical manipulation or imagined actions, confirming the beneficial effect of motor simulation on language comprehension. This supports the theory of embodied cognition, which emphasizes that cognitive activities depend on the embodiment of physiological structures, sensory experiences, and motor abilities. The embodied representation mechanism of abstract concepts is an important contribution of the theory, revealing that much of human abstract thought builds metaphorical frameworks through bodily experience. For instance, the metaphor of "time as space" derives from the experience of bodily movement in upright walking, and the division of social status into "high and low" is directly related to the perception of vertical bodily space [2].

3. Major theories of embodied cognition and distinction identification

While the importance of bodily experience in cognitive processes is emphasized by theories of embodied cognition, their fundamental mechanisms, ideal areas of application, and pedagogical implications vary greatly, and they provide a range of useful paths for language acquisition (see **Table 1**).

Conceptual metaphor theory suggests that the construction and comprehension of abstract concepts through concrete physical experiences, the construction and comprehension, "cross-domain mapping," is

effective in teaching abstract vocabulary and cultural concepts. For example, teachers can use gestures and spatial illustrations to assist students in understanding metaphors, such as upward gestures to indicate "future" and downward gestures to indicate "past," to help children connect abstract concepts of time to concrete spatial perceptions [2]. Perceptual symbolic systems theory emphasizes "simulation," that is, cognitive processes are the neural reactivation of past sensorimotor experiences. Teachers should design multimodal input teaching activities, such as allowing children to perform or observe actions while learning action words such as "grasping," to promote lexical understanding [1]. The core mechanism of the indexical hypothesis is the "real-time binding" and "action-language coupling" of language and action, which is advantageous in the teaching of verbs and descriptions of dynamic events. Teachers can design role-playing and action-imitation tasks to enhance children's reading comprehension [3]. Dual coding theory advocates "dual system representation," in which one channel is dedicated to language and the other channel is dedicated to non-verbal objects and events. When both systems are simultaneously stimulated (e.g., word + image), memory and comprehension could be enhanced [4]. Therefore, teachers should incorporate multimodal input such as images and videos in conjunction with multimedia tools to enhance vocabulary comprehension and memorization. Together, these theories provide multiple practical paths for language education.

In conclusion, the previously discussed theories reveal the internal processes behind embodied learning from several perspectives. They emphasize the significance of physical engagement and multisensory involvement in language acquisition, offering a robust theoretical framework for educators to develop more interactive and experiential instructional practices.

Table 1. Core mechanisms, domains of applicability, and pedagogical implications of different embodied cognition theories

Major theories	Fundamental mechanisms	Ideal areas of application	Pedagogical implications
Conceptual metaphor theory	Cross-domain mapping (concrete → abstract)	Abstract vocabulary, cultural concepts	Utilizing gestures and spatial illustrations to aid metaphor comprehension
Perceptual symbol system theory	Simulation mechanisms	Action vocabulary, embodied experience teaching	Designing multi-sensory teaching activities
Indexical hypothesis	Action-language binding in real time	Verbs, dynamic event descriptions	Designing role-playing, action-imitation tasks
Dual coding theory	Dual-channel encoding of verbal + nonverbal	Multi-meaning words, imaginative vocabulary	Combining multimodal inputs such as images and videos

4. Language learning theory from an embodied cognitive perspective

Children's language learning from the perspective of embodied cognition emphasizes the diversity of perceptual modalities. It believes that language learning is a comprehensive activity that is closely linked to the body's sensory and motor systems. The multisensory learning theory utilizes the synergy of multiple sensory modalities to enhance learning effects, whereas the action-based learning model highlights the core position of kinesthetic senses in language learning.

4.1. Multimodal input-based language learning theory

The embodied cognition theory emphasizes the significance of multisensory engagement in language acquisition, positing that language learning involves the integration of several modalities, such as visual,

auditory, and tactile elements. Mayer's Multimedia Learning Theory suggests that humans possess two distinct information processing channels, and that multimedia resources integrating auditory and visual input can enhance learning performance. The theory includes the principle for reducing extraneous processing, the principle for managing essential processing, and the principle for fostering generative processing, aiming at optimizing the learning process and improving the learning effect.

Multimodal learning enhances the learning experience by mobilizing multiple sensory and motor systems through diverse contexts. For example, when learning "curling," children can integrate perceptual-kinesthetic modalities and language input through multi-sensory participation and interactive design to enhance the learning effect.

4.2. Multisensory language learning theory

The perspective of embodied cognition on children's language acquisition underscores the importance of several perceptual channels, asserting that language learning involves not merely the comprehension of abstract symbols, but is also closely connected to the body's motor and sensory systems. Through the synergistic participation of multiple senses, children can understand and remember language knowledge more deeply and realize the organic integration of language with perception and movement [5]. This type of embodied cognition-based learning theory emphasizes multi-sensory participation, including multi-sensory enrichment and action-based learning.

The multi-sensory enrichment learning theory is an important part of the diversity of perceptual channels and centers on the use of synergistic effects of multiple sensory modalities to enhance learning [6]. The theory is based on the dual-coding theory, which suggests that information is encoded in both verbal and non-verbal forms, and that multisensory learning activates more neural pathways to improve memory persistence and accuracy [1]. For example, when learning the cello, providing pictures of the performance, animation, and hands-on opportunities can mobilize visual, auditory, and kinesthetic perceptions, thereby enhancing the learning experience and facilitating immediate comprehension of vocabulary and long-term memory [7]. The action-based learning model (ABL model) emphasizes the centrality of kinesthesia in language learning, arguing that language acquisition is closely related to the execution and observation of body movements [8]. By activating the mirror neuron system, children are able to make direct connections between verbal symbols and actual actions. For example, based on the Herbian principle of connections between simultaneously activated neurons, children who mimic an adult's use of a chisel when they hear the sound symbol "chisel" can form an integrated representation of the sound, action, and object in the brain, which facilitates vocabulary acquisition and functional understanding of language [8].

5. The realization of children's language learning from the perspective of embodied cognition

Embodied cognition theory provides a bridge from theory to practice for children's language education, emphasizing the promotion of language internalization and application through bodily perception, movement, and emotional experience. In specific teaching practice, this concept can be realized through imagery, gestures, enactment, multimedia aids, etc. These strategies mobilize children's multi-sensory system, connect abstract language symbols with concrete body experiences, and thus effectively enhance the learning effect.

5.1. Imagery

The imagery training method enhances children's comprehension and retention of linguistic skills by engaging multi-sensory experiences during the learning process. This method mainly includes mental imagery and dynamic visualizations. Mental imagery refers to the active construction of multimodal sensory representations based on linguistic materials, as well as the formation of embodied situational models by activating pre-existing perceptual, kinesthetic, and emotional experiences [9]. de Koning *et al*. [10] asked children to read "A Day at the Beach" and imagine that "she takes a ball of paper out of the wastebasket and throws it at her brother." The imagery of the scenario included visually seen characters (her and her brother), objects (the wastebasket and the ball of paper), tactile sensations (the rough, uneven ball of paper), emotional states (the two of them happily jostling), and importantly, kinesthetic imagery (the action of throwing it at each other). Studies have found that the use of mental imagery reinforces reading comprehension.

Dynamic visualizations through pictures, diagrams, or making drawings help children understand and recall linguistic skills more visually. For example, when learning the content of a story, children can construct characters and settings through illustrations on a storyboard. It not only improves children's reading comprehension but also enhances their understanding of abstract scientific texts [11]. Empirical studies have confirmed the positive effects of the imagery method on children's language acquisition. For example, Cohen and Johnson [12] used the imagery approach to establish a robust connection between target vocabulary and related perceptual experiences, achieving better learning results than the traditional definitional approach.

Despite the effectiveness of the imagery approach, there are some limitations to its application. First, the quality of mental imagery production is highly dependent on children's prior life experiences and perceptual reserves, which may limit its effectiveness with inexperienced children [1]. Second, over-reliance on external visual imagery may be detrimental to the development of children's ability to think abstractly and comprehend in depth independently when confronted with plain text [11].

5.2. Gesture and enactment

Gesture and enactment are the direct realization of embodied language learning. They can fully mobilize learners' visual and motor modalities, transforming language learning from static symbol reception to a dynamic, whole-body experience, and thus enhancing the effects of language memorization and comprehension [13].

Gestures can be categorized into three types——deictic gestures, cohesive gestures, and metaphoric gestures. These gestures add an extra dimension of visual and kinesthetic coding to linguistic information by presenting the meaning of vocabulary in a concrete, graphic, and kinesthetic way. For example, using the "smell" gesture to represent "flower" or demonstrating complex scientific concepts (e.g., the force of crustal plate interactions in earthquakes) through concrete hand motions can be effective in facilitating children's reading comprehension of abstract texts [14]. Gestures can also facilitate children's vocabulary acquisition. For example, repeated observation of figurative gestures helps learners produce vocabulary, and exercises that involve gesture recall and repetition can help reinforce memorization [13,14].

Enactment allows learners to mobilize a full range of perceptual-kinesthetic experiences in the scene and visualize linguistic content through actual action performances [3]. This approach is especially in line with children's active and learning-by-doing characteristics. The same approach applies in modern educational scenarios. For example, when learners are asked to perform the task described in a sentence (e.g., "Ben hooked the trailer to the tractor") by using the mouse and computer, studies have shown that this virtual manipulation, which combines physical action (manipulating the mouse) and imagery, is just as effective, and may even

surpass the efficiency of merely physical imagery manipulation [15].

A limitation of this approach is that the meanings of gestures and the social scripts played by the body are often highly culturally specific and need to be used with caution in cross-cultural teaching to avoid cognitive bias [16]. In addition, although technologies such as Augmented Reality (AR) have enhanced the efficiency of contextual play, how to avoid learners' over-reliance on visualization technologies, which may inhibit the development of abstract thinking, is a topic that needs to be addressed in future research [7].

5.3. Multimedia learning

Multimedia learning promotes learners' deeper understanding of content by integrating visual, auditory, and other sensory modalities [7]. These tools can effectively activate children's perceptual system and enhance language learning. Static multimedia tools such as pictures and diagrams support self-directed learning and exploration by providing stable visual cues that help children establish associations between linguistic symbols and concrete images [7]. Effective visual information can provide learners with figurative references to deepen their understanding of abstract language symbols. In addition, static images can be used as an aid to support children's independent learning and exploration during the reading process.

Dynamic visualizations such as animations and videos provide an immersive learning experience through dynamic visual and auditory stimuli that simulate real-life scenarios, allowing children to visualize the practical application of language and significantly enhance vocabulary and utterance comprehension [10]. Silverman [17] used video animation as input to learn relevant vocabulary, and found that repeated viewing of videos that reflect the meaning of vocabulary helped children to produce such vocabulary and improve language learning.

However, to maximize the efficacy of multimedia aids, the following points must be noted. First, the design of multimedia materials needs to strictly follow the principles of cognitive load theory, avoiding the inclusion of visual or auditory elements that are not related to the teaching content (e.g., fancy backgrounds and irrelevant music), so as to minimize the occupation of learners' cognitive resources. Second, multimedia aids should not be viewed in isolation and passively, but should be combined with active embodied activities, such as role-playing or hands-on manipulation while watching animation, in order to achieve optimal learning results. Finally, the selection and use of multimedia tools must be individually adapted to the child's age, cognitive level, and learning needs.

5.4. An integrated language learning framework for young learners in the setting of cognitive load and embodied cognition theories

Based on previous views and research evidence [18,19], we propose an integrated language learning framework involving embodied cognition and cognitive load (see **Figure 1**) and a new relevance-integration taxonomy for children's language learning (see **Figure 2**). It emphasizes that when body movements maintain high relevance and integration with the learning content, they are more conducive to reducing cognitive load. Teachers can flexibly adjust the intensity and tempo of movements by combining real-time feedback from eye movements and neuroimaging, thus enhancing the facilitation of deep and enduring linguistic representations by physical engagement (see **Figure 2**).

As shown in **Figure 1**, children's language teaching under the framework of Cognitive Load Theory (CLT) needs to follow a systematic process. When children are learning language tasks, cognitive offloading strategies, such as body movements (e.g., gesture simulation) or external tools (e.g., diagrammatic scaffolding) can be used to modulate cognitive load [20]. During the initial step, two activities must be completed simultaneously: identifying the goals of a given language task and undertaking a cognitive load analysis.

The analysis of cognitive load needs to distinguish among three categories: (1) High intrinsic cognitive load occurs when the task's inherent complexity, such as abstract vocabulary or complex syntactic structures, surpasses the learner's current ability; (2) Excessive extraneous cognitive load is indicated by the presence of redundant information or distracting instructional design; and (3) Insufficient germane cognitive load means the learner is unable to conduct deep cognitive processing to integrate the new learning materials into their existing knowledge framework [19]. Based on the diagnostic results, the use of embodied offloading strategies is recommended: (1) Physical offloading externalizes symbolic information to the motor system through gestures or enactment, which can reduce intrinsic load. (2) Instrumental offloading relocates spatial reasoning to a three-dimensional interface with the help of virtual technological tools or physical teaching aids, which reduces the extrinsic load. (3) Situational offloading embeds background knowledge into role-playing and storytelling scenarios in advance, releasing working memory resources to strengthen the generative load. (4) Social offloading further disperses individual cognitive pressure through peer collaboration and division of labor.

The four embodied offloading channels can only be used in the classroom if they are highly compatible with the child's age, language level, and linguistic task, and they are transformed into actionable instructions through the multisensory integration channels (visual, kinesthetic, and auditory synergies). Teachers need to monitor changes in learners' cognitive load in real time in the classroom to ensure that the offloaded resources are actually transformed into deep semantic processing rather than dispersed again. According to a recent review by de Koning *et al.* [18], the integration of embodied movement and cognitive load can be achieved through the following pathways: (1) When children encounter abstract vocabulary or complex syntax, teachers can mitigate intrinsic and extrinsic load by assisting them in learning vocabulary and grammar through virtual reality (VR) environments or by pointing out the key elements on screen; (2) Using stories to enhance students' memory and strengthen the germane load; (3) In emotional narratives or role-playing situations, enactment not only activates mirror neuron but also releases cognitive resources to strengthen the generative load.

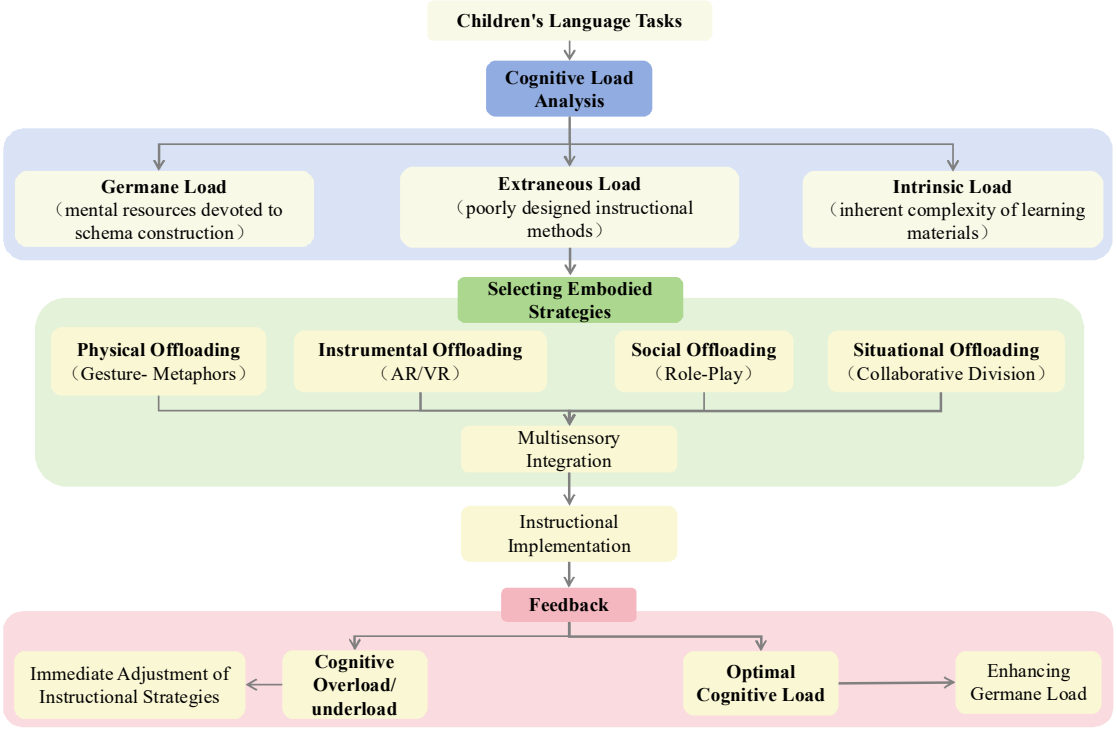

Figure 1. Integrated language learning framework involving embodied cognition and cognitive load

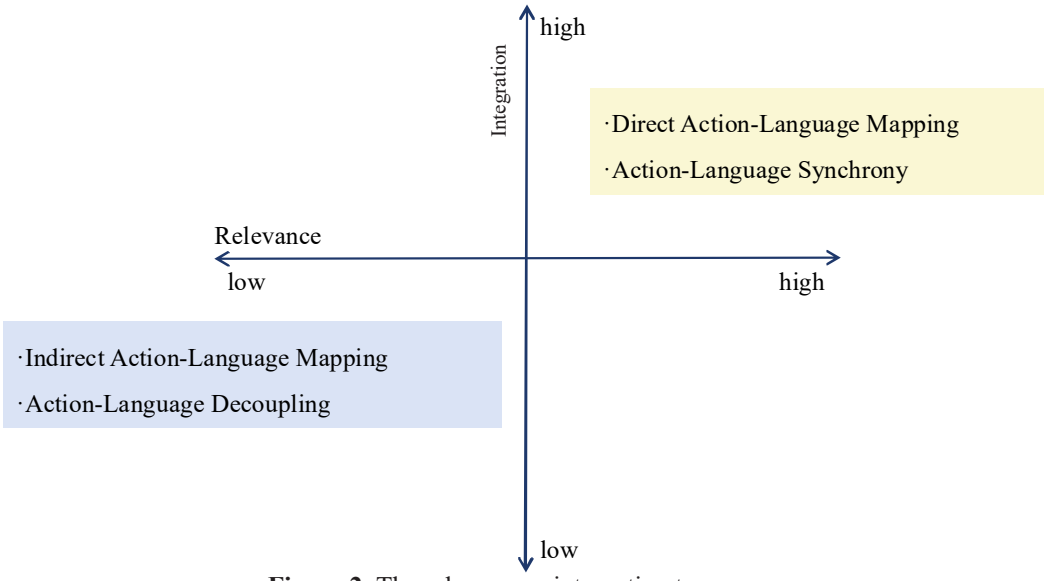

Figure 2. The relevance—integration taxonomy

6. Multiple factors affecting embodied language learning

Children's language learning outcomes are influenced by a range of learner characteristics and learning environment factors. Learner characteristics include age, language ability, decoding skills, and preferences in learning styles. Learning environments include the family environment, the school environment, and the socio-cultural context.

6.1. Learner characteristics

The age of children is a critical factor affecting the effectiveness of embodied learning. There are significant differences in cognitive abilities, language skills, and perceptual-kinesthetic development among children of different ages. A study by Block *et al.* [21] found that hand motor assistance in teaching reading strategies had the most significant effect on children in the kindergarten group, suggesting that younger children may benefit more from the embodied learning approach. In addition, a study by Xu *et al.* [22] showed that 4-year-old children performed better with kinesthetic interventions, while 5- and 6-year-old children performed better with visual interventions, suggesting that children's sensitivity to different embodied strategies varies by age. Therefore, the embodied learning approach is more conducive to language learning in young children.

The alignment between language ability and embodied strategies also affects learning outcomes, with embodied learning proving more effective for children with weaker language and reading skills. Rubman and Waters [23], in their 2000 study, showed that using silhouettes of people to create imagery was an effective stimulus for children with weaker reading skills. As another example, a published study [24] explored whether simultaneously observing and generating gestures while studying an instructional video reduced cognitive load and facilitated the acquisition of grammatical rules. The results of the study showed, contrary to expectations, that children in the simultaneous observation and generation of gestures condition performed worse on a posttest compared to a control condition in which no information about gestures was observed and gestures could not be made. Further analyses revealed that this negative effect on posttest performance was reflected in children with lower levels of language skills, but not in those with higher levels of linguistic competence. In summary, embodied learning strategies are negatively correlated with language proficiency, and the effectiveness of

embodied learning strategies decreases as children's language proficiency increases.

Decoding ability is also an important factor in the effectiveness of embodied learning for second-language children. Walker *et al*. [25] found that an intensive embodied perceptual learning method based on interactive technology was helpful for children with high decoding ability in illustrative text comprehension, and that those with high decoding ability could incorporate VR cultural contexts (e.g., virtual museum roaming) to drive deep memory through emotional resonance [26]. In contrast, there is no significant effect on children with poor decoding ability.

6.2. Learning environment factors

The family environment has a profound impact on children's language learning, and opportunities for rich language communication and interaction provide a platform for children to practice and imitate. Block *et al*. [21] introduced Comprehension Process Motions (CPMs) and emphasized that they can be transferred to the home environment: parents can use clarification gestures (CPMs) when reading a storybook. Parents can use clarifying gestures while reading a storybook to help their children express their confusion. This embodied engagement confirms Ye's [27] core idea that cognition is actively constructed through the body's sensory-motor system, whereby children interact with the environment to form knowledge and understanding through bodily movements.

In the school scenario, this mechanism is further shaped by the cultural context. Lakoff and Johnson [5] noted that culturally specific bodily experiences (e.g., spatial orientation, ritual gestures) form a metaphorical system, and that the construction of abstract concepts (e.g., time, morality) relies on culturally specific bodily experiences. This metaphorical cognition is rooted in the interaction between the body and the environment, which directly influences the way children understand and use language uniquely. Meanwhile, organizing activities such as role-playing and group discussion to encourage children to understand and use language through body movements and interactions can effectively enhance their language learning [28].

7. Opportunities and challenges

Embodied cognition theory introduces a new theoretical dimension for children's language learning, emphasizing that language learning is a comprehensive and dynamic process in which children's body, cognition, and environment interact closely. Embodied cognition methods such as imagery, gesture, enactment, and multimedia assistance can significantly enhance children's understanding and memorization of language knowledge. However, the application of these research findings encounters problems due to the constraints of educational resources and the necessity for educators to enhance their professional skills. Initially, there is a lack of teaching resources. Many schools and families have difficulties in supplying sufficient and suitable teaching aids and multimedia equipment due to budgetary limitations and limited space, which greatly affects the quality and effectiveness of embodied learning activities. Secondly, teachers' professional competence needs to be improved. The complexity and interdisciplinarity of embodied cognition theory make some teachers rusty in the application of the theory, and it is challenging to transform the theory of embodied teaching into vivid and effective teaching practice. When designing embodied learning activities, teachers need to take into account the detailed needs of children's differences, such as age, cognitive level, and learning styles, which puts higher demands on teachers' ability, experience, and educational sensitivity, and teachers' professional development and training need to be strengthened and improved.

8. Conclusion

In summary, embodied cognition theory overturns the traditional view of language education that advocates the separation of body and mind. It emphasizes that children's language learning is a dynamic process that involves the interaction of the body, the environment, and cognition. In this paper, we have systematically sorted out the major theories of embodied cognition, such as conceptual metaphor and perceptual symbol system, and explored the specific teaching and learning paths, such as imagery, gesture, enactment, and multimedia assistance. The central argument presented here is that effective embodied language teaching involves not only incorporating physical movements but also integrating embodied cognition theory with cognitive load theory. Specifically, teachers should first diagnose the cognitive load associated with children's language tasks and then implement "cognitive offloading" through the four embodied channels of body, tools, situation, and society. This method optimizes the learning processes by precisely regulating intrinsic, extraneous, and germane load.

Although embodied language teaching still faces the challenges of teaching resources and teacher competence in practice, it has a promising future. Embodied language learning in the preschool-primary transition should be emphasized in future research. Embodied language teaching models that better suit the physical and mental development of children at this stage should be explored, and teaching objectives and contents should be optimized accordingly to support the crucial improvement of children's language education.

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Disclosure statement

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