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A Study of Teaching Practices in Science under the Guidance of Embodied Cognition Theory

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Abstract: With the increasing proliferation and integration of science and technology in contemporary society, there has been a substantial surge in both the quantity and quality of individuals' demand for science education. As a result, the previously overlooked issue of science teaching has garnered attention from all stakeholders. The implementation of the Science Curriculum Standards for Compulsory Education (2022 Edition) (hereinafter referred to as the 'New Science Curriculum Standards') has expedited reforms in science education and provided explicit guidance for enhancing science teaching. Concurrently, embodied cognition theory, as a modern cognitive theory of learning, holds significant relevance to the field of science. Reassessing students' cognitive patterns within this framework offers fresh insights into addressing current challenges encountered in primary school science teaching and exploring practical strategies that align with modernized teaching and learning requirements: i. Enhancing exploration through immersive and dynamic multiple teaching contexts; ii. Promoting school-based curricula to foster family practice and social projects; iii. Utilizing universally accessible and user-friendly technological learning products while exploring online-offline modes for embodied teaching and learning.

1. Introduction

In order to comprehensively enhance the core scientific literacy of our students, the science subject has prioritized the cultivation of students' ability to practice and inquire as one of its major teaching objectives. Building upon this principle, the New Science Curriculum establishes a broader and more rigorous standard for practical and inquiry-based learning compared to the original curriculum. To meet this standard, all stakeholders, including science teachers, must actively transform their traditional conceptions of science teaching and adapt their instructional strategies in order to genuinely foster the development of students' core scientific literacy. In this paper, we employ embodied cognition theory to elucidate the significance of physical actions in primary school science learning and endeavor to explore a science learning model that integrates both 'bodily cognition' and 'thinking cognition' within an immersive environment.

2. Origin of the Study

2.1. Escalation of the Demand for Science Education by the Subjects Concerned

Science education shoulders the important task of cultivating future scientific and technological innovative talents and improving the scientific literacy of citizens[1] . Since entering the new era of technology, the demand for science education from all parties, including the state, the society and the people, has undergone quantitative and qualitative upgrading. The country needs more innovative and practical scientific and technological talents; the post-epidemic society has higher requirements for the scientific literacy of all citizens; along with the advancement of education reform, mastering part of the scientific knowledge is no longer enough to meet the people's self-development needs for the informatization and diversification of social environments, and the people pay more and more attention to the scientific intelligence, emotion, and the experience of practical innovation. It is precisely because of these evolving needs for science education that China's education authorities have launched a continuous reform and optimization of science subjects in terms of educational objectives, methods, personnel, standards and resources.

2.2. Update of Curriculum Standards for the Science Discipline

The Ministry of Education issued the New Science Curriculum Standard on 21 April 2022, emphasizing the cultivation of students' core literacy in scientific concepts, scientific thinking, practical inquiry, and attitudes and responsibilities to establish a foundation for lifelong development [2]. In comparison with the 2017 version of the curriculum standard, the new science standard further enhances its nurturing orientation by explicitly defining "inquiry and practice" as both a learning mode and goal. The revised definition of "practical inquiry" incorporates "technical and engineering practical ability" and "independent learning ability," building upon the original concept of "scientific inquiry ability." Similarly, the definition of "scientific inquiry" now includes elements such as "technical and engineering practical ability" and "independent learning ability," supplementing its initial focus on scientific investigation. These modifications highlight that the New Science Curriculum places significant emphasis on fostering students' practical skills alongside their capacity for inquiry. This approach necessitates not only theoretical exploration but also real-life application of knowledge while simultaneously enhancing students' meta-cognitive abilities.

2.3. Science Teaching Practices Face Formalized Dilemmas

Compared with the requirements of the New Science Curriculum, there exists a discernible disparity between the actual teaching situation and the standards. The underlying reason for this discrepancy lies in our teaching system and concepts struggling to adapt to the modern and humanistic demands of education. In practical science instruction, three common phenomena have been observed: Firstly, the evaluation method compels a testing-oriented approach to teaching. "Paper and pencil tests" serve as the predominant means of assessment in science subjects, allowing for a relatively simplistic quantification of students' knowledge mastery. However, employing paper-and-pencil tests to evaluate a science curriculum that aims at fostering students' comprehensive abilities and core literacy appears excessively one-sided. Concurrently, inter-school ranking competitions force teachers to train their students solely for test-taking purposes by instilling repetitive knowledge through intensive exercises. While this practice has proven effective in yielding higher scores among students, it contradicts the pedagogical principles stipulated in the New Science Curriculum. Moreover, relying on paper-and-pencil assessments fails to fulfill its intended functions of promoting comprehensive, equitable, and developmental teaching practices; rendering such competitions meaningless both among schools and individual students. Secondly, A diversified teaching environment is recommended by the New Science Curriculum, which suggests developing science teaching environments that combine in-school and out-of-school settings, nature and society, as well as physical and online platforms based on curriculum needs. However, most actual teaching fails to meet these requirements, with classrooms and laboratories remaining the primary learning environments. Moreover, due to a lack of specialized administrators in laboratories, many laboratory materials and environmental resources are wasted. Additionally, science teachers tend to use laboratories in a manner similar to classrooms without fully utilizing their functionality. Thirdly, formalized inquiry practices often prevail over authentic experimentation. In such cases, teachers provide students with prepared materials for mechanical completion of experimental procedures without encouraging deep thinking or fostering innovative approaches. Simultaneously, during instruction processes, practical applications are limited to theoretical or idealized models rather than real-life problem-solving using scientific principles or other relevant scenarios from students' lives; thus resulting in a significant disconnect between classroom learning and real-world experiences.

3. Analysis of the Theory

3.1. Overview of the Theory of Embodied Cognition

The traditional theory of cognition adopts Descartes' view of mind and body, in which Descartes believed that true knowledge can only be obtained through perfect rational reasoning of the mind, and that the body is merely a vessel for knowledge and does not actively participate in the cognitive process[3-4]. We refer to this cognitive theory as 'disembodied cognition theory'. With advancements in cognitive disciplines, the validity of the 'disembodied cognition theory' has been increasingly challenged, with some psychologists asserting that the mind does not exist independently but rather relies on the physiological structure and activities of the body. This perspective is known as 'embodied cognition theory[5]. It was notably advocated by French psychologist Merleau Ponty, who argued for an embodied perception of the world[6]. In other words, cognition is intricately linked to both brain function and bodily engagement within an environmental context; thus forming a unified whole[7]. Evidence from various scientific studies, including functional magnetic resonance imaging, further supports that human intellectual and emotional cognition is deeply rooted in interactions between the body and its environment[8]. Consequently, embodied cognition theory offers a more scientifically grounded approach compared to disembodied cognition theory. Presently, it stands as one of contemporary classical theories within cognitive science research[9].

Based on the emergence of embodied cognition theory, new concepts such as embodied learning and embodied teaching have been proposed[10]. Their common feature lies in their emphasis on "embodied action" where "embodiment" refers not only to direct bodily involvement but also to the experience of the body within a specific context[11]. Thus, embodiment serves as both the origin of cognitive differences and cognition itself. According to different conditions of embodied experiences, embodiment can be categorized into three types: actual embodiment, virtual embodiment, and offline embodiment. Yin and Liu liken these types respectively to "eating plums to quench thirst," "looking at plums to quench thirst," and "thinking of plums to quench thirst", reflecting individual experiences, situational awareness, and psychological arousal associated with each type[12].

3.2. Implications of Embodied Cognition Theory for Science Teaching

The theory of embodied cognition has implications for both students' science learning and teachers' science teaching, emphasizing the importance of exploring the body as a primary agent in learning. It advocates for experiential and immersive teaching strategies that integrate theoretical knowledge with practical applications, aligning with the core literacy goals of the New Science Curriculum. In contrast to traditional disembodied education models, the mind-body interactive education model enhances learning vitality by enabling students to grasp knowledge concretely, develop problem-solving skills, and leverage individual differences to stimulate creativity and adaptability in transforming their environment. Considering the specific image-based thinking characteristics of primary school students, it becomes evident that embodied cognition theory is highly relevant to science subjects' learning and holds significant operational value in addressing current challenges in primary school science teaching while promoting educational reform.

4. Teaching Practice Strategies of Science Subject under the Guidance of Embodied Cognition Theory

The theory of embodied learning holds significant practical value in guiding the implementation of science teaching, particularly in meeting the requirements of the New Science Curriculum and effectively addressing the practical challenges faced under test-oriented education. To this end, several suggestions are proposed for employing this theory to guide primary school science teaching practices.

4.1. Exploring Immersive and Life-like Teaching and Learning Contexts

The fundamental concept of contextual cognition posits that the human mind undergoes development within specific contexts and relies on the collaborative interaction between individuals, their surroundings, and the physical environment [13]. Teaching contexts not only provide learners with direct applications of knowledge or patterns of contingency but also foster a genuine desire for learning through authentic experiences within these contexts [14]. Within this framework, the teaching and learning context encompasses both the physical environment in which students reside as well as social, cultural, and psychological environments. It can manifest as a realistic situation or a simulated scenario designed to facilitate teaching and learning. This context may be physical or virtual in nature. Currently, educational institutions have fallen behind in terms of formulating design ideas for learning spaces that align with evolving educational concepts; instead, they exhibit strong industrial standardization reminiscent of an era focused on mass production. To accommodate embodied learning effectively, traditional learning spaces must inevitably undergo a series of transformations [4]. What kind of learning space is required to meet the needs of primary school science teaching activities?

On one hand, in order to address the issue of formalizing inquiry in science education, teachers should actively transform their teaching methods from passive listening to experiential or immersive approaches [7]. This shift involves moving from a focus on cognitive processes alone to collaborative blended learning that integrates both mind and body. Furthermore, it entails transitioning from an emphasis on mechanical learning towards fostering creativity [15]. Notably, immersive learning is an extension of experiential learning that emphasizes deep immersion, effective interaction, and high-quality experiences. By enhancing student engagement and motivation through increased participation, immersive learning facilitates profound understanding and enables students to construct meaningful cognitive experiences encompassing both physical and mental aspects[7].

On the contrary, teachers should prioritize the development of practical pedagogical approaches within the instructional context. At the elementary education level, teachers' teaching methods significantly influence students' cognitive processes. For instance, in a public classroom setting, when posed with the question "what constitutes an insect," students promptly respond with "three pairs of legs and two pairs of wings; body divided into head, thorax, and abdomen." However, when asked to provide examples of common insects in their daily lives, responses become varied. This indicates that students lack a clear understanding of the concept of insects. The underlying cause for this phenomenon can be attributed to pseudo-practical activities frequently observed in current science classrooms. Curriculum standards necessitate connecting theories with practice; therefore, after acquiring scientific knowledge, teachers often guide students towards linking theoretical concepts from textbooks to real-life applications through what is known as "expansion and application." Nevertheless, many primary school students have not encountered these real-life scenarios presented in textbooks beforehand. Consequently, these theoretical applications remain abstract symbols devoid of tangible practical significance.

Therefore, how can we establish an effective teaching environment? In order to achieve this goal, teachers need to shift their teaching paradigm and prioritize quality over quantity in regular classes. They should thoroughly understand the students, curriculum, and teaching environment to create a practical teaching situation that meets the students' needs. The concept of practical teaching should be integrated into both the design and implementation of regular lessons. Teachers must allocate sufficient time, space, and resources for students to practice the curriculum using real-life issues as learning opportunities. Additionally, they should consider students' physical actions and cognitive development when addressing their learning styles while also targeting multidimensional objectives encompassing knowledge acquisition, intellectual growth, emotional intelligence, and behavioral development. Fulfilling these requirements places significant demands on teachers; thus ensuring their accomplishment becomes crucial. "Apart from teachers' individual efforts, schools and education-related institutions should actively contribute to providing them with learning platforms and resources. It is crucial to address the issue of teacher professional development, as the author believes that China's current approach to teacher training needs reform and innovation in order to enhance its effectiveness. Teachers are burdened with teaching responsibilities while also having to invest significant time and energy into various forms of training such as seminars, conferences, open lectures, listening sessions, and continuing education. However, among their busy schedules, it is worth reflecting on whether these activities truly improve the quality of education and instruction. For instance, many teachers are required to participate in full-time e-learning programs which tend to be lengthy and extensive. Unfortunately, some resort to a superficial approach by simply playing the lessons on their computers without actually engaging with the content or seeking answers online for assessment purposes. This formalized training has become ingrained in teachers' routines. Therefore, it is imperative that research be conducted on teacher training methods along with improvements in assessment techniques and frequency based on research findings in order to enhance efficiency. The aim should be for training programs to serve teachers rather than making them merely comply with training requirements.

Simultaneously, the creation of teaching contexts by science educators heavily relies on the support of school resources, particularly evident in science education. The teaching of scientific subjects necessitates access to laboratories and experimental materials, as well as utilization of natural resources both within and outside campus environments. This may involve off-campus factory investigations or visits to science and technology museums. Consequently, schools should actively foster an environment that encourages teachers to innovate their teaching contexts while providing them with adequate hardware resources, financial stability, institutional backing, and manageable channels for support. Additionally, clear, detailed operational supervisory regulations should be established encompassing conditions for engaging in scientific practices, safety protocols and systems, as well as feedback mechanisms assessing effectiveness. Furthermore, a platform ought to be established for teachers that offers increased opportunities for sharing experiences, demonstrating best practices, learning from others' expertise and facilitating exchange.

4.2. Developing Family Practice and Social Practice Programs Using School-based Curricula

Embodied action serves as a conduit for individuals to explore knowledge, evoke emotions, and construct values, while also serving as a crucial means to authenticate cognition[14]. Learners comprehend, internalize, and transfer knowledge through action, thereby establishing an inseparable trinity of the learner's body, mind, and environment that significantly enhances learning efficacy[7]. The discipline of primary school science itself derives from practical life experiences; concurrently, the New Science Standard mandates practice as one of the principal avenues for primary school students to acquire scientific knowledge. Therefore, actively fostering practical projects and enabling students to engage in embodied action-driven inquiry not only aligns with the fundamental principles governing students' construction of scientific cognition but also represents the most efficacious approach for primary school students to grasp scientific principles and cultivate core literacy.

Currently, primary schools offer various practical science activities such as STEM projects, maker activities, and science and technology festivals. However, it is important to note that practical science activities should not be limited to the campus environment alone; they should also extend to the family and social environments. Unfortunately, many schools have not fully utilized these two resources due to their uncontrollable nature. Implementing practical activities in these environments requires not only teacher design and guidance but also the involvement of family members and community members, making it time-consuming, labor-intensive, and challenging to ensure effectiveness. Nevertheless, family and social practice activities play a crucial role in students' understanding of science, learning process, self-monitoring and reflection abilities, interaction with diverse groups, lifelong learning skills development - thus forming an indispensable part of students' inquiry-based learning in science. In comparison with campus practical activities that are constrained by factors like time availability or limited space/resources/personnel/ content/ performance orientation dimensions; family and social practical activities provide more independent space for action opportunities while leveraging individual experiences among students effectively breaking through limitations imposed by campus inquiries on space/resource/target dimensions - thereby enhancing students' practical skills development as well as fostering innovation capabilities which can complement campus-based practical activities. Therefore, in light of the prevailing deficiency of practical education within families and society, it is imperative to consider the practical challenges associated with developing these two resources while also devising gradual implementation strategies. On one hand, when designing the content for family-based practical activities, it is essential to fully account for regional characteristics and formulate tasks that encompass universally applicable and moderately specialized subject matter. These tasks should have low material requirements, adopt open formats, and place high emphasis on physical practice. For instance, examples include observing an animal and describing its distinctive features in a personal manner or cultivating a plant while regularly documenting its growth process. Secondly, it is crucial to respect the variations in individual home environments by refraining from imposing campus-based standards upon students' home practice activities. Instead of focusing solely on outcomes achieved, greater attention should be given to students' embodied actions and reflective processes during these activities which ought to possess multidimensional educational qualities. Additionally, certain regions may establish a platform for communication regarding family-based practices or introduce a science practice board within campus applications or platforms under governmental supervision as means for facilitating questions and exchanges between students and parents during such activities; this platform can also serve as a reference point for other families but must not be obligatory. Furthermore, leveraging campus science and technology festivals can create opportunities for sharing experiences related to family-based practical activities thereby fostering both scientific inquiry models within families as well as advancing family education development.

On the contrary, the advancement of the social practice component within practical scientific activities necessitates immediate educational policy endorsement. This is primarily due to the fact that social practice encompasses not only the actions undertaken by various stakeholders within educational institutions but also requires support and collaboration from external societal entities and channels. Inadequate policy regulations and supervision deter all parties involved from allocating resources and undertaking substantial risks. Moreover, parents express concerns regarding their children's participation in extracurricular science-related activities without comprehensive safeguards. In response to these challenges, some schools will invite external experts to participate in demonstrations or educational activities, thereby reducing the risk of students leaving the school premises. This approach can be categorized as a mode of 'real-life embodiment' education, which enhances students' cognitive experience. Compared to teachers' explanations, professionals' explanations and demonstrations in this mode are more comprehensive, in-depth, and specialized. Additionally, students find it refreshing and experiential. However, in terms of teaching effectiveness, this mode is slightly inferior to the 'true sense of embodiment'. The most noticeable drawback is that students tend to passively observe professionals without actively engaging in physical actions or deep thinking. Consequently, many students only remember the occurrence of such events but completely forget the related learning content over time. Therefore, out-of-school practical activities for students are indispensable. Education departments, teachers, schools, social organizations insurance agencies and families should all be involved in formulating and supervising scientific and social practice programs for students. These programs should strive for embodied interaction while ensuring student safety. Furthermore they can incorporate emotional education on a case-by-case basis since emotions often receive inadequate attention within regular science classes.

4.3. Progressively Applying Intelligent Teaching Tools and Innovating Online-offline Integrated Teaching Models

With the rapid advancement of technology, a multitude of technologies such as somatosensory systems, virtual reality (VR), augmented reality (AR), naked eye 3D, and artificial intelligence (AI) have emerged successively, significantly expanding our perception of the human body [9]. When applied to embodied teaching in primary school science education, these technologies not only provide students with enhanced learning tools and methods but also create novel learning contexts that cater to the diverse needs for context-based science learning. Moreover, they compensate for the limitations of traditional offline contexts which are often singular, challenging to create and expensive. For instance, in SMALLab's virtual laboratory environment, learners can engage in various collaborative tasks encompassing topics ranging from simulating chemical particle decomposition to exploring the relationship between throwing and flying – experiences that are otherwise difficult for learners to encounter in real-world situations[16]. In Chinese primary school science education practices, some teachers have utilized VR technology to teach about the internal structure of the human body. By allowing students to experience simulated real-life scenarios during this process, their cognitive understanding is more effectively constructed compared to traditional instructional approaches.

However, due to the exorbitant cost associated with these devices and their limited adoption among science teachers, only a handful of schools possess a meager quantity of such equipment and employ them sparingly. How can we foster the development and rationalize the utilization of this genre of technical apparatus? Firstly, considering that primary school students possess relatively low levels of experimental proficiency and cognitive aptitude, there is no imperative need for highly sophisticated equipment; instead, it would be more prudent to develop uncomplicated yet captivating science and technology learning products tailored to teaching and learning requirements. For instance, collaborative efforts between expert and technologists could yield virtual instructional aids or web-based science games. Secondly, it is essential to provide training for science teachers in online technologies while encouraging active exploration of online embodied teaching cases so as to gradually acclimate them to modern education's technological demands while continuously enhancing their digital literacy skills. Teaching ethics necessitate lifelong learning engagement by educators encompassing not just subject knowledge and educational theories but also all pedagogical methods and skills requisite for effective instruction. Lastly, owing to the fact that the content within the science curriculum itself draws from real-life scenarios rather than virtual realms coupled with China's nascent state in terms of online educational technology advancement renders it somewhat unsuitable for inquiry-based or practical scientific learning at the primary level. Therefore, teachers should prioritize students' cognitive rules and subject characteristics when designing their teaching approach, integrating online and offline resources based on curriculum needs. They should also engage students both physically and mentally to foster interaction between their body, mind, and environment in order to cultivate core scientific literacy. By promoting this integration of the virtual context with the real world through emerging technologies, a highly interactive and personalized learning environment can be created to facilitate learner participation - an important trend in the development of blended learning models[17].

5. Conclusion

Education itself is inherently contemporary and social in nature. The fundamental objective of education is to enhance the quality of life for individuals. Ensuring high-quality science education holds paramount importance in fostering a healthier and happier modern society. Primary science education has garnered increasing attention within China's educational reform, necessitating urgent resolution of previously neglected or shelved teaching practice issues. Simultaneously, the theory of embodied cognition advocates for the inclusion of the body in classroom settings, enabling active participation throughout the learning process—an essence akin to Tao's advocacy for knowledge-action integration[10]. This aspect stands as a cornerstone within Chinese science education, serving as a crucial direction for future teaching reforms in China while also possessing strong applicability and guiding significance towards primary school science curriculum reform.

However, it is imperative to adopt a dialectical perspective on the role of the body in science curriculum learning. Firstly, not all scientific content can be effectively conveyed through embodied learning strategies; rather, embodied learning should be integrated and aligned with the specific content for optimal outcomes[9]. The advantages of embodied learning cannot entirely supplant those of traditional teaching methods such as lectures, demonstrations, and discussions. Instead, it serves as an updated and supplementary approach to science education. Consequently, the future science classroom should embrace a pluralistic, multi-dimensional, multi-subjective, interactive, and humanized mixed teaching mode that transcends mere technological advancements or resource enhancements. Moreover, implementing embodied teaching strategies in current basic education systems characterized by both test-oriented education and quality education poses challenges due to insufficient attention given to science subjects within China's evaluation mechanism –

encompassing students' attitudes towards science subjects along with parental expectations and societal perceptions – which necessitates substantial resources and conditions from all stakeholders involved. Science teachers are burdened by their multifaceted roles that demand continuous learning endeavors while striving for innovation breakthroughs. Nonetheless, it is evident that as science education continues its development and reform journey forwardly embarking upon collaborative digital teaching strategies will gradually permeate into future science classrooms.

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