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The Current Status of Empirical Research on Deep Learning within the Educational Domain

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Abstract: Deep learning, as an efficient and proactive mode of learning, has garnered extensive attention in the educational domain. This paper systematically reviews the connotations and empirical research status of deep learning, aiming to provide references and insights for subsequent studies. Initially, the connotations of deep learning are thoroughly explored from aspects such as conceptual definition, characteristic analysis, and its correlation with cognitive theories, thereby clarifying its pivotal role in education. Subsequently, the themes, methods, contexts, and outcomes of empirical research on deep learning are meticulously analyzed, revealing the current research hotspots and trends, and pointing out the deficiencies and limitations in the existing studies. Finally, a critical review of the existing literature is conducted, and directions for future research are proposed. The research findings indicate that deep learning significantly enhances academic performance, knowledge comprehension, learning experience, and the development of thinking and capabilities. However, further in-depth and extended research is still required, especially in terms of the comprehensiveness of research themes, the richness of research methods, and the diversity of research contexts.

Keywords: Deep Learning, Current Status of Empirical Research, Empirical Research.

1. Introduction

In the context of the knowledge economy era, the educational domain is confronted with unprecedented challenges and opportunities. With the rapid advancement of information technology, there have been profound transformations in learning methods, teaching models, and the pathways of knowledge dissemination. Deep learning, as an efficient and proactive approach to learning, has gradually garnered extensive attention from educational researchers and practitioners. Deep learning emphasizes that learners, based on an understanding of knowledge, engage in critical thinking, integrate information, construct knowledge systems, and apply the acquired knowledge flexibly to solve practical problems, thereby cultivating higher-order thinking skills and lifelong learning capabilities. It has significant advantages in enhancing the quality of learning, promoting the internalization and innovative application of knowledge, and has become one of the hot topics in educational technology research. However, current literature reviews on deep learning within the educational field predominantly employ knowledge mapping analysis methods, which superficially present the sample distribution, basic trends, and research hotspots of a certain category of studies. There is a scarcity of systematic descriptions, classifications, and analyses targeting the empirical research on deep learning, failing to assist readers in understanding the teaching design, successful pathways, and evaluation methods of deep learning at the operational level. This study aims to systematically organize and analyze research literature on deep learning both domestically and internationally, to reveal its connotations and the current status of empirical research, and to critically review the existing studies, thereby providing references and insights for subsequent research.

2. The Connotation of Deep Learning

2.1. Definition of Deep Learning

The concept of deep learning was initially proposed by Marton and Saljo (1976), who, based on the learners' methods of acquiring and processing information, categorized learning into two types: deep learning and surface learning. Deep learning refers to the learners' active and critical understanding of learning materials, connecting new knowledge with existing knowledge and experiences to form a structured knowledge system, and applying the acquired knowledge flexibly to solve problems in different contexts. This concept has provided a foundational framework for subsequent research, prompting educational researchers to begin focusing on the deep processing and understanding of knowledge by learners during the learning process (Marton & Saljo, 1976).

2.2. Characteristics of Deep Learning

(1) Proactivity

Deep learning emphasizes the principal role of learners, who play a crucial part in this process. They are no longer passive recipients of knowledge but actively participate in learning activities, delving into the learning content. This proactivity is reflected in the learners' clear setting of learning goals, autonomous selection of learning strategies, and self-monitoring and regulation during the learning process. For instance, in project-based learning, learners need to actively collect materials, design research plans, and solve problems, all of which require their active engagement and contemplation to achieve the goals of deep learning (Entwistle & Ramsden, 1982).

(2) Criticality

Criticality is one of the core characteristics of deep learning. Learners, during the process of deep learning, critically examine learning materials, questioning, analyzing, and reflecting on the knowledge acquired, rather than blindly

accepting others' viewpoints. They engage in in-depth thinking about the sources, content, and structure of knowledge, striving to form their own unique understanding and insights. This critical thinking helps learners identify errors or deficiencies in knowledge, promoting a deeper understanding and innovative application of knowledge. For example, in academic research, researchers need to critically analyze the results of previous studies, identifying existing problems and deficiencies, thereby advancing the development of academic theories (Biggs, 1987).

(3) Integrativeness

Deep learning focuses on the integration of new and old knowledge. Learners, in the learning process, integrate newly acquired information with existing knowledge structures to build a more complete and systematic knowledge system. This integration includes not only the content of knowledge but also involves the integration of learning methods and thinking patterns. Through integration, learners can connect fragmented knowledge points to form an organic knowledge network, enhancing the internal connections and logic of knowledge, thereby better understanding and applying knowledge. For example, in interdisciplinary learning, learners need to integrate knowledge from different disciplines to solve complex interdisciplinary problems (Postareff et al., 2015).

(4) Constructiveness

Deep learning is a constructive learning process. Learners, in this process, actively construct the meaning of knowledge and form personalized cognitive structures through communication, cooperation, and practical operations with others. Constructivist theory posits that learning is a process in which learners, based on their existing knowledge and experiences, actively construct the meaning of knowledge through interaction with the external environment. Deep learning is a typical manifestation of constructivist learning; learners, in real contexts, construct and reconstruct knowledge by exploring and practicing, integrating new knowledge with existing knowledge. For example, in experimental teaching, students actively construct their understanding of scientific concepts through hands-on operation of experimental equipment, observation of experimental phenomena, and analysis of experimental results (Peng et al., 2017).

(5) Transferability

Deep learning emphasizes the application and transfer of knowledge. Learners are able to flexibly apply the knowledge they have learned in different contexts to solve practical problems, achieving the expansion and extension of knowledge. This transferability is not only reflected in the horizontal transfer of knowledge, that is, applying knowledge from one field to other fields, but also in the vertical transfer, that is, applying foundational knowledge to higher-level learning. Through transfer, learners can concretize abstract knowledge and apply theoretical knowledge to practice, enhancing their ability to solve practical problems. For example, in engineering practice, engineers need to transfer theoretical knowledge to specific engineering projects to solve problems in engineering design, construction, and management (Zhang Hao & Wu Xiujuan, 2012).

3. The Current Status of Empirical Research on Deep Learning

In the realm of empirical research on deep learning, this paper categorizes the studies conducted by domestic and international researchers into four dimensions: research topics, research methodologies, research contexts, and research outcomes, and elaborates on each respectively.

3.1. Research Topics

(1) Deep Learning Strategies

Research on deep learning strategies aims to explore effective methods and means to promote learners' deep learning. Researchers have proposed a variety of deep learning strategies from different perspectives. For instance, Peng et al. (2017) constructed a virtual learning environment to visualize the complex programming process. The results indicated that this strategy not only improved students' academic performance but also effectively stimulated their intrinsic motivation for learning. Moreover, cooperative learning, problem-based learning, and case teaching have also been proven to be effective strategies for promoting deep learning. Cooperative learning, through the interaction and collaboration among group members, enables learners to deepen their understanding of knowledge through communication; problem-based learning starts from real-world problems, guiding learners to actively explore solutions, thereby cultivating their critical thinking and problem-solving abilities; case teaching, through the analysis of specific cases, allows learners to acquire knowledge in context, enhancing their ability to apply knowledge (Postareff et al., 2015). However, the applicability and effectiveness of different strategies vary across different disciplines and learning contexts, necessitating further research to optimize the implementation of these strategies.

Among the myriad of deep learning strategies, cooperative learning, with its unique interactivity and synergy, has become one of the focal points of researchers. Studies have shown that cooperative learning provides learners with a diversified interactive learning platform. In the process of communication and collaboration among group members, learners can examine issues from different angles, inspire each other's thinking, and jointly explore solutions, thereby deepening their understanding and mastery of the learning content (Johnson & Johnson, 1999). For example, when solving complex problems, group members can express their own views, share their knowledge and insights, and through brainstorming, find more comprehensive and innovative solutions. In addition, cooperative learning can also cultivate learners' team collaboration skills and communication techniques, laying the foundation for their future cooperation in society and the workplace.

Problem-based learning, as a learning strategy driven by real-world problems, also holds an important position in deep learning research. This strategy combines learning content with real-world problems, stimulating learners' curiosity and desire to explore, prompting them to actively use their acquired knowledge to analyze and solve problems (Barrows, 1996). In the process of problem-based learning, learners need to deeply analyze the problems, identify the key points and difficulties, and then collect information and integrate knowledge purposefully, using critical and creative thinking to find solutions. This process not only deepens learners' understanding of knowledge but also exercises their problem-solving and innovative thinking abilities, enabling them to flexibly apply their acquired knowledge in real contexts.

The case teaching strategy presents learners with specific and vivid cases, allowing them to deeply understand the

learning content and master the application methods of knowledge through analysis and discussion of the cases (Christensen, 1981). In case teaching, learners need to carefully analyze the context, characters, and events in the cases, and explore the underlying issues and principles, thereby achieving deep processing and internalization of knowledge. For example, when learning management theories, by analyzing typical cases of business operations, learners can better understand the application of management theories in actual work, enhancing their ability to connect theory with practice.

(2) Deep Learning Approaches

Research on deep learning approaches focuses on the cognitive processing methods adopted by learners during the learning process. It has been found that deep learning approaches have different connotations under various conceptual frameworks, and their influencing factors are complex and diverse. In addition to demographic factors, self-efficacy, learning motivation, learning engagement, and learning environment experiences may all have direct or indirect impacts on deep learning approaches (Postareff et al., 2015).

Research findings indicate that deep learning approaches do not exist in isolation but are influenced by a combination of various factors. Self-efficacy, as learners' subjective evaluation of their learning abilities, significantly affects their deep learning approaches (Zimmerman, 2000). When learners possess high self-efficacy, they are more inclined to adopt deep learning approaches because confident learners believe in their ability to understand and master the learning content, thus being more willing to invest time and effort in exploring learning materials in depth. Conversely, learners with low self-efficacy may opt for surface learning approaches due to a lack of confidence, merely focusing on superficial memorization and simple understanding of knowledge.

Learning motivation, the internal driving force that propels learners to engage in learning activities, also has a significant impact on deep learning approaches (Ryan & Deci, 2000). Intrinsic motivation, such as interest in learning content and a thirst for knowledge, can prompt learners to actively and positively engage in deep learning, as they derive satisfaction and a sense of achievement from the learning process. On the other hand, extrinsic motivation, such as the desire to achieve good grades or avoid punishment, can also motivate learners to some extent, but it often fails to stimulate their enduring drive for deep learning. Moreover, the intensity of learning motivation also affects the stability and continuity of deep learning approaches; strong learning motivation enables learners to persevere in the face of learning difficulties and consistently employ deep learning approaches.

Learning engagement, the sum of attention, energy, and emotional resources that learners invest in the learning process, also plays a crucial role in deep learning approaches (Fredricks et al., 2004). Highly engaged learners focus intently on learning tasks, actively think, and explore, engaging deeply with learning materials, thereby more easily achieving deep learning. In contrast, learners with low engagement may be distracted and perfunctory in their approach to learning materials, failing to achieve the effects of deep learning. Learning engagement encompasses not only cognitive engagement, such as thinking, analyzing, and synthesizing, but also emotional engagement, such as emotional experiences and value identification with learning content, as well as behavioral engagement, such as actively participating in learning activities and communicating with others.

The impact of learning environment experiences on deep learning approaches should not be overlooked. A supportive and interactive learning environment can provide learners with rich learning resources and opportunities for communication, making it easier for them to immerse themselves in the learning context and develop the willingness for deep learning (Vygotsky, 1978). For example, in the classroom, teachers create positive learning atmospheres by setting contexts, organizing discussions, and providing feedback, enabling learners to engage in deep learning in a relaxed and pleasant environment. In contrast, a suppressive and communication-poor learning environment may inhibit learners' thinking activities and enthusiasm for learning, hindering the occurrence of deep learning.

(3) Deep Learning Assessment

Research on deep learning assessment aims to establish a scientific and effective evaluation system to assess learners' levels and effects of deep learning. Researchers have gradually recognized that traditional assessment methods, primarily based on examination scores, fail to comprehensively reflect learners' deep learning situations. Therefore, diversified, process-oriented, and performance-based assessments have attracted increasing attention (Shen et al., 2019). For instance, process-oriented assessment focuses on evaluating learners' performance during the learning process, including their participation, application of learning strategies, and reflection and adjustment during the learning process; performance-based assessment evaluates learners' levels of deep learning through observing their performance in actual tasks, such as project outcome presentation and problem-solving. In addition, self-assessment and peer assessment have also been introduced into the evaluation of deep learning to enhance the subjectivity and interactivity of the assessment. However, how to design scientific and reasonable evaluation indicators and methods, and how to effectively integrate different evaluation approaches, still require further research and exploration.

3.2. Research Methods

(1) Data Collection Methods

In terms of data collection, empirical research on deep learning employs a variety of methods to obtain comprehensive and accurate research data. The questionnaire survey method, known for its efficiency and convenience, is widely used in investigations of deep learning approaches or capabilities (Shen et al., 2019). Researchers design scientifically sound and reasonable questionnaires to collect extensive data on learners' attitudes, strategies, and motivations towards learning, providing a foundation for subsequent analysis. The interview method is often utilized in small-scale qualitative studies, where in-depth communication with learners yields detailed information about their learning processes, such as learning experiences, difficulties encountered, and reflections (Postareff et al., 2015). Additionally, observation, testing, and document analysis methods are also applied in deep learning research. Observation records learners' behavioral manifestations during the learning process, provide researchers with intuitive data; testing assesses learners' mastery of knowledge and skills; document analysis, through the examination of learners' assignments, notes, and reflection logs, provides

insights into their learning processes and cognitive trajectories.

(2) Data Analysis Methods

Regarding data analysis methods, quantitative analysis predominates, with researchers utilizing statistical software to process and analyze the large volumes of collected data, deriving conclusions of general applicability (Shen et al., 2019). For instance, methods such as descriptive statistical analysis, analysis of variance, and regression analysis are employed to study differences in deep learning approaches among learners under various teaching conditions and the effectiveness of deep learning strategies. However, as research progresses, qualitative analysis methods have also gained increasing importance. Researchers employ qualitative analysis methods such as content analysis and thematic analysis to delve into the complexities of learners' inner worlds and learning processes (Postareff et al., 2015). Mixed-methods analysis, combining the strengths of both quantitative and qualitative approaches, offers a more comprehensive revelation of the characteristics and patterns of deep learning, providing researchers with a richer perspective.

3.3. Research Contexts

(1) Disciplinary Fields

Empirical research on deep learning spans across multiple disciplinary fields, with a concentration in social sciences and natural sciences. Within the realm of social sciences, deep learning has been applied to disciplines such as education, psychology, and sociology, where researchers have explored its specific manifestations, facilitation strategies, and the enhancement of disciplinary competencies (Shen et al., 2019). For instance, in educational research, deep learning has been utilized for teacher professional development and the reform of teaching methods to improve teaching quality and student academic achievement. In the natural sciences, deep learning has found extensive application in physics, chemistry, and biology, with empirical studies validating its effectiveness in promoting students' understanding of scientific concepts and the development of scientific inquiry skills (Postareff et al., 2015). The specific representations, facilitation strategies, and application outcomes of deep learning vary across different disciplinary backgrounds, providing rich material and challenges for interdisciplinary research.

(2) Educational Stages

Regarding educational stages, empirical research on deep learning predominantly focuses on the higher education stage, with university students as the primary subjects of study (Shen et al., 2019). Researchers have conducted a series of empirical studies in universities to investigate the application of deep learning in various majors and courses, as well as its impact on university students' academic performance, critical thinking, and innovative capabilities. However, there is also a growing interest in deep learning among middle school students, elementary school students, and adult learners. For example, in the basic education stage, researchers have attempted to integrate the concept of deep learning into classroom teaching through reforms in instructional design and innovations in learning activities to foster the occurrence and development of deep learning among primary and secondary school students (Postareff et al., 2015). In the field of adult education, deep learning has been applied to vocational training and lifelong learning to enhance the professional competencies and adaptability of adult learners.

3.4. Research Outcomes

Empirical research outcomes have generally confirmed the significant effects of deep learning in enhancing academic performance, knowledge comprehension, learning experiences, and the development of thinking and capabilities. Specifically, deep learning facilitates students' in-depth understanding and long-term retention of knowledge, thereby improving academic achievements (Shen et al., 2019). For instance, classes employing deep learning strategies tend to exhibit superior examination scores compared to those using traditional teaching methods. Moreover, deep learning improves learning experiences, providing learners with greater satisfaction and pleasure during the learning process, thus enhancing intrinsic motivation (Postareff et al., 2015). In terms of thinking and capability development, deep learning plays a crucial role in cultivating students' higher-order thinking skills, such as critical thinking, creative thinking, and problem-solving abilities. Through deep learning, students are better able to analyze problems, propose solutions, and engage in innovative designs (Peng et al., 2017). However, a minority of studies have found that in certain circumstances, deep learning does not yield the expected learning outcomes, which may be associated with the scientific nature of intervention design, the supportiveness of the teaching environment, and individual differences among learners. Therefore, further research and exploration are needed to optimize the implementation strategies of deep learning and enhance its effectiveness across different contexts.

4. Review of Literature

Overall, research on deep learning has yielded fruitful results, providing numerous beneficial insights for educational practice. On a theoretical level, researchers have conducted in-depth explorations into the connotations, characteristics, and mechanisms of deep learning, forming a relatively systematic theoretical framework that lays the foundation for understanding the essence of deep learning. On a practical level, a wealth of empirical studies has revealed the application effects of deep learning in different disciplines and teaching environments, providing empirical evidence for instructional design and the reform of teaching methods, thereby promoting innovation and development in educational practice. Additionally, research has developed several measurement tools and evaluation methods for deep learning, offering technical support for assessing learners' levels of deep learning and the effectiveness of teaching interventions.

Despite the many advancements in deep learning research, there are still some deficiencies and limitations. Firstly, in terms of research topics, studies on the occurrence process of deep learning, resource construction, and motivation stimulation are relatively weak, failing to fully reveal the entirety of deep learning. Secondly, regarding research methods, although mixed-methods analysis is gaining increasing attention, the depth and systematic nature of qualitative research need to be strengthened, and the complexity of learners' inner worlds is not sufficiently explored. Moreover, in terms of research contexts, studies on deep learning among primary and secondary school students and adult learners are relatively scarce, with a focus mainly on the higher education stage, failing to comprehensively cover learners at different educational stages. Lastly, in the interpretation and application of research results, some

studies lack in-depth analysis of factors such as intervention design and teaching environment, which limits the generalizability and practical guidance of the research findings.

Future research on deep learning can be further deepened and expanded in the following aspects. First, there should be an enhanced multidimensional exploration of the connotations of deep learning, comprehensively understanding its complexity from cognitive, emotional, and social perspectives. Second, a richer and more in-depth range of research methods should be adopted, such as case study and narrative research qualitative methods, to deeply explore learners' learning processes, experiences, and reflections, as well as the roles and strategies of teachers in promoting deep learning. Third, the research context should be broadened to strengthen studies on deep learning across different educational stages and disciplinary backgrounds, exploring application models and effects in diverse educational environments. Fourth, attention should be paid to the long-term effects of deep learning, with longitudinal tracking studies conducted to examine its long-term impacts on learners' academic achievements, capability development, and career adaptability. Fifth, interdisciplinary research should be strengthened, integrating theories and methods from multiple disciplines such as education, psychology, cognitive science, and information technology, to provide a broader perspective and stronger support for the research on deep learning.

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