Journal of Education and Educational Research
ISSN: 2957-9465 | Vol. 7, No. 1, 2024

A Systematic Review on Deep Learning in Education: Concepts, Factors, Models and Measurements

Jing Chen [1], Charanjit Kaur Swaran Singh [2]

[1] Infrastructure University Kuala Lumpur, Kuala Lumpur, Malaysia
[2] University Pendidikan Sultan Idris, Boulder, Kuala Lumpur, Malaysia

Abstract: Deep learning, a cognitive process involving goal alignment, advanced problem-solving, and rigorous knowledge application, lacks a unified framework despite its wide application in education. This gap poses challenges for researchers, educators, and policymakers. A meticulous review of ten pertinent articles published between 2019 and 2023, aimed to define the concept, identify influencing factors, examine research models, and scrutinize measurement methods. Results show that while "deep learning" is commonly used, a clear, unified definition is absent. Influencing factors are proposed based on diverse theoretical frameworks, including individual and environmental elements. Commonly referenced models are Biggs' 3P model and Bloom's taxonomy. Data collection predominantly employs surveys, interviews, and experiments, with a bias towards quantitative analysis, supplemented by qualitative methods. It's worth mentioning that there is a growing trend in the use of mixed methods. This study provides valuable insights for the effective implementation of empirical deep learning research. It provides practical references bridging theory and practice for education researchers.

Keywords: Review; Deep Learning; Definition; Factors; Models; Measurements.

1. Introduction

The Deep Learning Theory is a valuable framework for higher education curricula design, spanning face-to-face, hybrid, and online settings [1]. Although deep learning research shows diverse and remarkable results, a notable gap remains in systematic organizational research. Despite numerous studies on deep learning methods in higher education, applying the findings practically is challenging without a comprehensive overview. This underscores the need for an effective analysis of the field.

Initially, the conceptualization of deep learning was introduced by Ference Marton and Roger Saijo in 1976 within the realm of education. They articulated the deep approach (DA) and surface approach (SA) to distinguish between learning for meaningful comprehension and rote reproduction [2]. Biggs further categorized learning styles into surface learning and deep learning, positing that learners opt for distinct methods based on various learning tasks, resulting in divergent learning outcomes. Additionally, scholars have explored fundamental characteristics [3], influencing factors [2,4,5], conceptual models [2,3,6], and other dimensions of deep learning to address diverse research objectives. This comprehensive exploration has significantly enriched the research framework of deep learning.

Deep learning, beyond theoretical exploration, has found extensive practical application and support in education. The international education community increasingly emphasizes nurturing creative thinking, critical thinking, and problem-solving skills over traditional knowledge transmission. The introduction of deep learning models has revitalized education, prompting a focus on cultivating comprehensive competencies to adapt to the rapidly changing modern society. Supported by organizations like the Hewlett Foundation, deep learning research gained traction, with an 8-year project initiated in 2014. The 2017 Horizon Report predicted the pivotal role of deep learning in higher education decision-making. Varied approaches, such as project-based, challenge-based, and inquiry-based learning, contribute to dynamic learning experiences. Studies, including one by AIR (2022), affirm the positive impact of deep learning on student outcomes in high schools, reinforcing its recognition as a vital educational approach in the modern world [7,8].

Despite widespread references and applications of deep learning, there is no established unified definition, theory, or practical framework. The challenge stems from the diverse and complex nature of the educational landscape, which introduces variations in interpreting and applying deep learning across contexts. The absence of this unified foundation poses challenges for researchers, educational practitioners, and policymakers advocating for deep learning. Firstly, the lack of a clear definition and framework leads to diverse interpretations and a deficiency in common terminology and standards. Secondly, implementing deep learning methods in teaching becomes challenging due to a lack of clear guidance and strategies. Additionally, the absence of standardized definitions and evaluation criteria complicates assessing the effectiveness of deep learning methods, hindering the comparison of research outcomes. The resulting variability in interpretations may yield inconsistent results across similar studies. Ultimately, the absence of a unified theoretical framework poses difficulties for education policymakers and practitioners in formulating policies and practices, impeding the development and dissemination of deep learning in education. Therefore, establishing a unified definition, theory, and practical framework is crucial for effectively promoting the implementation of deep learning in education.

2. Methods

The inconsistency in research findings so far may impede our ability to uncover the complex relationships that may exist in research and practice. To navigate the procedural intricacies of empirical research, it becomes essential to delineate its foundational components [9]. The research methodology employed in this literature review adheres to the framework proposed by Dinsmore and Alexander [9], encompassing a systematic review and synthesis of findings from multiple empirical studies. The aim is to find the most suitable approach to deep learning, which can be readily implemented and adapted by educational researchers and learners, providing them with a more accessible pathway. In line with the four research objectives - conceptualization, operationalization, contextual factors, and model specification - this study undertakes a content analysis across four dimensions: research themes, concepts, contextual factors, and models and measurements.

The data collection followed a systematic research method aligned with the PRISMA approach, the acknowledged standard for presenting evidence in systematic reviews and meta-analyses. To delineate the research landscape of deep learning in the last five years, literature searches were executed using the ProQuest, Web of Science, and Springer Link databases. Ten articles were scrutinized to address the research questions, selected based on specific criteria: 1) Refereed academic journals to ensure high-quality refereeing; 2) Published in the last five years (2019–2023); 3) Indexed by ProQuest, Web of Science, and Springer Link databases; 4) Discussing deep learning in education; and 5) Written in English. Following manual screening, articles not directly related to artificial intelligence technology were excluded, resulting in a total of 10 articles.

3. Findings and Discussion

3.1. Concepts

According to the first research objective, which is "to elucidate the concept of deep learning," two specific issues were identified. The first entailed an analysis of the prevalence of definitional keywords. The second involved an assessment of the explicitness of the definitions, representing the core content of the provided definitions.

The first issue involves analyzing prevalent definitional keywords. Deep learning is approached differently across literature, lacking a universally recognized definition. Expressions like "deep processing" [9,10], "deep approach" [5,6,11], "deep learning strategy" [3,12], and "deeper learning" [13] describe the concept in education, but "deep learning" is most common [2,4,14,15]. This study adopts the keyword "deep learning" based on consistent literature usage.

The second issue focuses on assessing the explicitness of deep learning definitions. Various researchers present distinct definitions, emphasizing either the learning process or outcomes. Approached as a process [2,6,11,12, 15], deep learning enhances problem-solving and decision-making abilities, involving critical understanding and linking of new concepts. Biggs' work is frequently referenced, defining deep learning as involving strategies like critically understanding new concepts and linking ideas [12]. Weng [15] succinctly summarize deep learning as engaging in critical learning and reflective processes within authentic contexts. As an outcome, deep learning is seen as a set of competencies, including critical thinking, problem solving, collaboration, communication, and learning to learn [4,13]. Advance HE (2020) defines five competencies—critical thinking, problem solving, collaboration, communication, and learning to learn—as pivotal components of deep learning [4]. Otto [13] define outcomes as sustainably integrated knowledge in terms of knowing, applying, and reasoning, along with a motivational component (fascination).

In conclusion, despite diverse definitions in prior scholarly works, achieving a unified delineation of deep learning remains elusive, hindering rigorous research in theoretical and practical domains. Aligned with the constructivist paradigm [16], deep learning is seen as a cognitive process yielding corresponding outcomes through the reconstruction of prior knowledge. This research, firmly grounded in constructivist principles and incorporating global perspectives, defines deep learning as an advanced cognitive process guiding learners to specific outcomes. This intricate process involves formulating objectives, comprehending, analyzing, and resolving complex problems, and judiciously synthesizing, transferring, and innovating knowledge.

3.2. Factors

According to the second research objective, which is "to delineate the factors that exert influence on deep learning", two key issues were identified. The initial phase involves examining researchers' perspectives on studying these influencing factors, followed by assessing the impact of various factors on deep learning.

Initially, the study examines researchers' perspectives concerning the investigation of factors influencing deep learning. Various studies have systematically explored and postulated factors affecting deep learning from diverse viewpoints, frequently employing theoretical frameworks. This body of research emphasizes the potential moderation of these frameworks by their associated factors. Pioneering organizations engaged in deep learning research acknowledge critical thinking, problem-solving, collaboration, communication, and learning as fundamental 21st-century skills integral to the deep learning process [4]. Sabah [3] operationalized behavioral objectives based on Bloom's taxonomy in the context of mathematics classes, aligning with the identified factors.

Significantly, the work of Biggs has garnered considerable attention, evident in a multitude of citations [2,6,11,14,15]. This underscores the substantial impact of Biggs' research within the academic community, where scholars frequently utilize his work as a foundational framework in their studies. For instance, Han [6] operationalized Biggs' 3P Model of Classroom Learning, employing the R-SPQ-2F questionnaire to validate factors influencing deep learning. However, LoGiudice [14] raised concerns about the predictive validity of such inventories, highlighting the need for further empirical studies to refine tools for assessing deep learning outcomes. This underscores a significant gap in understanding how specific measures can consistently signify the occurrence of deep learning, emphasizing the urgency for more research in this area. Addressing these gaps can enhance our comprehension of deep learning in the educational context.

3.2.1. Individual Factors

A pivotal determinant shaping deep learning is the individual factors of learners, as substantiated by an array of studies [3, 5, 6,11]. Sabah [3] underscored the significance of learner characteristics, such as an active pursuit of understanding the subject matter and materials, indicative of self-motivation and the ability to connect new ideas with existing knowledge. Zhang [5] posited that students' experiences are impacted by a multitude of factors encompassing themselves, the class, the institution, and the profession. Xie [11] identified noteworthy disparities in deep learning levels among students based on demographics such as gender, ethnic backgrounds, socioeconomic statuses, academic years, and institutional affiliations. Han [6] further integrated individual factors, encompassing gender, age, family social and cultural capital, and personality traits.

Significantly, perceptual factors of students, including learning motivation, self-efficacy, and interest in learning, are extensively explored in the literature [6, 11, 13]. Han [6] asserted that students' perceptions of the external learning environment can influence self-efficacy, career aspirations, achievement goal orientation, and other intrinsic factors. Xie [11] observed that students demonstrating elevated levels of intrinsic and instrumental motivation, as well as social motivation, tend to adopt deep learning approaches. Otto [13] delved into students' motivation to learn, identifying a genuine fascination with the subject matter as a critical factor.

While the research provides valuable insights into the influence of individual factors on deep learning, several limitations should be acknowledged. Firstly, the studies may not capture the full diversity of learners' experiences, often concentrating on specific demographics or institutional contexts. Secondly, there is a lack of thorough exploration of potential interactions between individual factors. Thirdly, although the studies acknowledge external factors like the socio-economic environment, cultural influences, and familial support systems, their specific impacts are not deeply investigated. Therefore, a mixed methods, combining quantitative data with qualitative insights through interviews or surveys to gain a more nuanced understanding of the interplay between individual factors and deep learning.

3.2.2. Learning Environment Factors

The learning environment stands out as a crucial determinant influencing deep learning, as affirmed by numerous researchers. Deep learning's impact on students necessitates an environment empowering them to make choices, take charge of their learning, and apply knowledge both within and beyond the classroom [5]. Educators play a pivotal role in implementing diverse course evaluation systems and cultivating a learning environment that motivates students to prioritize comprehension and mastery of knowledge.

Various studies have explored instructional methods in learning environments, assessing distinctions from traditional teaching approaches. Jamil & Bhuiyan [4] demonstrated the capability of the simulation teaching approach in a virtual reality environment to facilitate specialized content. Weng [15] validated the effectiveness of combining design-based learning (DBL) with outcome-based education (OBE) in enhancing students' deep learning. The Horizon Report in 2015 recognized project-based learning, problem-based learning, inquiry-based learning, and challenge-based learning as methods facilitating more interactive learning experiences.

Disciplines or professions also play a significant role, as discussed in many studies [5,6,13]. Zhang [5] surveyed early childhood education majors, finding that curriculum reform extent is influenced by students' career plans. Han [6] revealed a positive correlation between clear career goals and promoting deep learning, while unclear goals may hinder development.

While current research highlights the crucial role of the learning environment in facilitating deep learning and underscores the educator's significance, there are areas requiring further investigation. Designing effective teaching approaches for different disciplines or professions necessitates substantial empirical research to demonstrate their effectiveness. This includes a deeper exploration of specific elements within the learning environment, a detailed understanding of the effectiveness of diverse instructional methods, and the optimization of teaching approaches for enhanced deep learning outcomes. Addressing these aspects contributes to a more comprehensive understanding of how to effectively promote and facilitate deep learning in educational settings.

3.3. Models

According to the third research objective, which aims to "specify the models used in the implementation of deep learning," an attempt was made to outline the theoretical frameworks used for each study. The challenge in this undertaking was that the explicit mention of the theoretical framework was rare in most cases. For example, Sabah [3] specifically referenced Bloom's taxonomy as their framework, but did not provide further explanation or discussion on it; Li [2] and Han [6] specifically referenced the 3P model as their framework for studying deep learning. Han [6] further explained the influencing factors within the framework and applied it in empirical research. However, the norm for these studies was either only a reference to some framework [3] or an introduction that alluded to a particular framework [4]. In the rare cases where a framework was explicitly mentioned, this was not a problem; however, it was very difficult to determine in cases where references or conceptual allusions to a framework were made if the authors intended to use the referenced or alluded to models or theories as the frameworks for the study.

Nonetheless, this initial foray into investigating the framework did reveal two different types of frameworks invoked for deep learning. The two frameworks discussed here include Biggs's 3P model [2,6], Bloom Taxonomy [3]. It is important to acknowledge the theoretical frameworks because these frameworks are what allow researchers to systematically test the relations between deep and surface processing and learning outcomes and organize the findings. In other words, differences found in the relations between levels of processing and learning outcomes may be explained by the different interpretations placed upon the data by the theoretical frame employed.

3.3.1. Biggs's 3P Model

Individual factors assume a pivotal role in shaping deep learning, a consensus supported by diverse studies [3,5]. Sabah [3] underscores the significance of learner characteristics, emphasizing self-motivation and the ability to connect novel ideas with existing knowledge. Zhang [5] accentuates the constraints on students' experiences emanating from factors within themselves, the class, the institution, and the profession. Xie [11] delineates disparities in mean levels of deep learning among students based on gender, ethnic background, socioeconomic status, academic years, and institutional affiliations. Han [6] further delves into individual factors, considering gender, age, family social and cultural capital, along with personality traits.

Moreover, perceptive factors of students, including learning motivation, self-efficacy, and interest in learning, find extensive discussion in the literature [6,11,12,13]. Han [6] posits that students' perceptions of the external learning environment influence self-efficacy, career aspirations, achievement goal orientation, and other intrinsic factors. Hava [12] acknowledges career aspirations as potential influential factors. Xie [11] observes that students exhibiting elevated levels of intrinsic and instrumental motivation, alongside social motivation, tend to embrace deep learning approaches. Otto [13] underscores the critical role of genuine fascination with the subject matter as a motivating factor.

While these studies provide valuable insights into the influence of individual factors on deep learning, certain limitations should be acknowledged. Firstly, they may not capture the full diversity of learners' experiences, often concentrating on specific demographics or institutional contexts. Secondly, potential interactions between individual factors are not thoroughly explored. Thirdly, although external factors like socio-economic environment, cultural influences, and familial support systems are acknowledged, their specific impact is not deeply investigated. Therefore, employing a mixed-methods approach, combining quantitative data with qualitative insights through interviews or surveys, would provide a more nuanced understanding of the interplay between individual factors and deep learning.

3.3.2. Bloom's Taxonomy

Bloom's Taxonomy, which classifies cognitive learning into six levels—knowledge, comprehension, application, analysis, synthesis, and evaluation—is widely referenced in education. Sabah [3] applied it to investigate the impact of deep learning strategies on high school students' math scores and practical intelligence. The Reverse Thinking model, studied by Weng [15], is grounded in Bloom's Taxonomy.

However, despite its widespread recognition and use in studies [3,15], Bloom's Taxonomy faces criticism in teaching. The primary critique revolves around its categorization of learners based on final outcomes, neglecting the dynamic cognitive development process and hindering the accurate assessment of deep learning initiatives. The hierarchical nature of objective classification, implying a linear progression, is not universally applicable. Studies often incorporate higher-order cognitive skills into deep learning, relegating "knowledge and comprehension" to surface-level learning, oversimplifying the intricate interplay between these levels. In reality, mastery of one level doesn't necessarily depend on complete proficiency at the preceding level, and skill acquisition may not unfold sequentially. This complexity poses challenges to assessment models in accurately capturing the nuanced process of changes and growth in deep learning endeavors.

3.4. Measurements

According to the third research objective, which aims "to identify the measurement employed in the implementation of deep learning," an attempt was made to outline the measurements used for each study.

In the realm of deep learning research, scholars have extensively utilized various metrics to conduct cross-disciplinary and cross-cultural comparative studies, aiming to validate the structural integrity and dimensions of their assessments [3,4, 6,11, 12, 13,15]. According to the above findings (as summarized in Table 1), the predominant data collection method, employed in 90% of cases, was the questionnaire approach. Its popularity stems from its efficiency in swiftly accumulating data from a large pool of research subjects. The experimental method, chosen in 30% of studies, was used to capture shifts in students' knowledge, cognitive processes, and abilities before and after implementing deep learning intervention strategies. Additionally, the interview method was utilized in 40% of cases, particularly in smaller-scale qualitative research, to gain deeper insights into the processes and outcomes of deep learning. Notably, many studies employed a combination of data collection methods to mitigate the limitations inherent in each individual approach.

Table 1. Measurements

No.	Author(s)	Surveys	experiment	focus groups	interviews
1	Sabah et al. (2023)		post-test experiment (N=61)		
2	Li et al. (2022)	R-SPQ-2F(N=368)			
3	Jamil and Bhuiyan (2021)	Reflection-based survey (n = 112)		three focus groups(N=11)	
4	Zhang et al. (2021)	Student questionnaires			1. student interview 2. lecturer interview
5	Hava (2021)	1. R-SPQ-2F(N=97) 2. student questionnaire (N=97)	pre and post-test experiment (N=97)		student interview (N=12)
6	Otto et al. (2020)	1.Fascination questionnaire (N = 711) 2. test (N = 688)			
7	Sharma et al. (2023)	R-SPQ-2F (n=278)			
8	Xie et al. (2023)	Chinese College Student Survey (n = 67,182)			
9	Han et al. (2023)	R-SPQ-2F (n=273)			student interview (N=16)
10	Weng et al. (2023)	1.SPQ (n=78) 2. Deep learning questionnaire (n=78)	pre and post-test experiment (N=97)		student interview (N=3)

In reviewing empirical research literature, the Study Process Questionnaire (R-SPQ-2F) by Biggs emerged as the most commonly used assessment tool [2,14, 6,15]. The Student and Teacher Survey Documentation, along with the National Survey of Student Engagement, initially designed for use in the USA, have been adapted for Chinese students [11]. Some researchers have also developed or modified scales to measure deep learning according to their research objectives [13]. However, it's important to note that these scales may not have undergone rigorous psychometric testing and validation, potentially limiting the comparability of their results with other studies.

4. Conclusion and Suggestions

The intricate and varied theoretical framework of deep learning poses challenges for researchers. This study aims to navigate these challenges by exploring the conceptual definition, influencing factors, research models, and measurement methods within the empirical literature. The overarching goal is to provide a comprehensive overview of deep learning research, encompassing theory and practice and unveiling the content and process of empirical investigations in this domain. This endeavor aims to assist learners in discovering effective methods to promote deep learning while providing educators with accessible and implementable references. The key conclusions drawn from this study include:

Conceptual Definition: The term "deep learning" is prevalent in research, yet a unified and clear definition remains elusive. Biggs' conceptualization is frequently cited, prompting this paper to refine the conceptual description and definition for more precise guidance.

Influencing Factors: Various theoretical frameworks inform factors influencing students' deep learning. Notably, Biggs' 3P model and R-SPQ-2F questionnaire are frequently cited, demonstrating the effectiveness of key factors, including individual and environmental elements.

Research Models: Exploration of frameworks allows systematic examination of the relationship between deep learning and learning outcomes. Two prominent frameworks, Biggs' 3P model and Bloom's taxonomy, provide a valuable reference for selecting theoretical frameworks in subsequent empirical research.

Measurement Methods: Commonly employed data collection methods include questionnaires, interviews, and experiments. Quantitative analysis predominates, with qualitative analysis playing a supplementary role. The rising interest in mixed-methods analysis is noteworthy, with Biggs' R-SPQ-2F questionnaire standing out as a frequently used tool.

In summary, this study delves into the nuanced realm of deep learning, addressing challenges posed by its intricate theoretical framework. Through an examination of empirical literature, the study defines the concept, identifies influencing factors, explores research models, and scrutinizes measurement methods. The ultimate objective is to provide a comprehensive overview of deep learning research, bridging the gap between theory and practice. This endeavor seeks to elucidate the content and process of empirical studies on deep learning, offering valuable insights for learners and practical references for education researchers.

References

[1] Pereira, A. S., & Wahi, M. M. (2019). Deeper Learning Methods and Modalities in Higher Education: A 20-year Review. Journal of Higher Education Theory and Practice, 19(8), 48-71.

[2] Li, B., Burke, J., & Plunkett, M. (2022). Deep or surface learning? Perceptions of Chinese international and local students in Australian universities. Issues in Educational Research, 32(1), 149-181.

[3] Sabah, S. H., Ban, H. M., & Areej, K. H. (2023). Impact of Deep Learning Strategy in Mathematics Achievement and Practical Intelligence among High School Students. International Journal of Emerging Technologies in Learning (Online), 18(6), 42-52.

[4] Jamil, M.G., Bhuiyan, Z. (2021). Deep learning elements in maritime simulation programmes: a pedagogical exploration of learner experiences. International Journal of Educational Technology in Higher Education, 18, 18.

[5] Zhang, N., Zhao, H., & Guo, K. (2021). A deep active learning approach to exploring young adults' learning in a picture book elective. Australian Journal of Adult Learning, 61(2), 216-240.

[6] Han, T., Huang, L., & Hao, L. (2023). Changing Trajectories and Formation Mechanism of Deep Learning Approach: A Longitudinal Study of the Undergraduate Experience in the Educational Interface. Asia-Pacific Education Researcher.

[7] Adams Becker,s.,Cummins,M.,Davis, A.,Freeman,A.. HallGiesinger, C., and Ananthanarayanan, V.(2017).NMC HorizonReport: 2017 Higher Education Edition. Austin, Texas: The NewMedia Consortium.

[8] Kristina L. Zeiser, Ji Hyun Yang, Catherine Bitter, and Dana Shaat (2022). The Study of Deeper Learning: College Enrollment, Persistence, and Degree Completion in the First 6 Years After High School.

[9] Dinsmore, D. L., & Alexander, P. A. (2012). A critical discussion of deep and surface processing: What it means, how it is measured, the role of context, and model specification. Educational psychology review, 24, 499-567.

[10] Marton, F., & Säljö, R. (1976). On qualitative differences in learning: I—Outcome and process. British journal of educational psychology, 46(1), 4-11.

[11] Xie, M., King, R.B., & Luo, Y. (2023). Social motivation and deep approaches to learning: a nationwide study among Chinese college students. Higher Education, 85, 669–687.

[12] Hava, K. (2021). The effects of the flipped classroom on deep learning strategies and engagement at the undergraduate level. Participatory Educational Research, 8(1), 379-394.

[13] Otto, S., Körner, F. A., Marschke, B. A., Merten, M. J., Brandt, S., Sotiriou, S., & Bogner, F. X. (2020). Deeper learning as integrated knowledge and fascination for Science. International Journal of Science Education.

[14] LoGiudice, A.B., Norman, G.R., Manzoor, S., et al. (2023). Does a deep learning inventory predict knowledge transfer? Linking student perceptions to transfer outcomes. Advances in Health Sciences Education, 28, 47–63.

[15] Weng, C., Chen, C., & Ai, X. (2023). A pedagogical study on promoting students' deep learning through design-based learning. International Journal of Technology and Design Education, 33, 1653–1674.

[16] Bada, S. O., & Olusegun, S. (2015). Constructivism learning theory: A paradigm for teaching and learning. Journal of Research & Method in Education, 5(6), 66-70.