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# DEEP LEARNING IN BLENDED LEARNING ENVIRONMENTS: A SYSTEMATIC LITERATURE REVIEW

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**Abstract:** This study aimed to review research on students' deep learning in blended learning environments. The study examined 29 peer-reviewed scholarly publications from the Web of Science using the PRISMA approach. Results show that effective deep learning practices in blended environments depend on several interconnected strategies, including student-centered approaches like flipped classrooms, multimodal resources, experiential learning, strong teaching presence, and social interaction. Assessment strategies have evolved from recall tests to authentic assessments, reflection prompts, formative feedback, and AI-driven analytics. For implementation, educators should align online materials with face-to-face activities, provide appropriate scaffolding, embed metacognitive reflection, integrate technology thoughtfully, and offer personalized feedback. Approaches should be tailored to different learning contexts and disciplines. This systematic literature review identifies gaps in previous research and suggests directions for future studies, including longitudinal investigations of deep learning trajectories and more robust combinations of AI-driven analytics with qualitative data.

***Keywords:*** deep learning of students, blended learning environments, educational technology, systematic review.

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## INTRODUCTION

In the age of globalization, the goal of education is no longer to cultivate mechanized, test-oriented learners but to develop qualified individuals who can adapt to the 21st century (Kuhlthau et al., 2015). Many countries, such as the United States, Japan, Singapore, and Malaysia, have proposed new objectives for student development in the information age (Reimers & Chung, 2019). As a symbol of high-level learning and an important way to cultivate students' 21st-century skills, deep learning has attracted increasing attention from researchers (Fullan et al., 2018). The 2017 Horizon Report by the New Media Consortium (NMC) and the "Horizon Report on Chinese Higher Education—Focusing on the Application of Technology in Chinese Higher Education," published by the Smart Learning Institute of Beijing Normal University, both highlight a key trend in technology application: the shift

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from tangible learning forms and spaces to intangible innovation and deep learning (Gao & Huang, 2017).

The blended learning environments rely on hardware and information technologies, such as smart devices and mobile learning applications, combining the characteristics of "internet-enabled smart devices" and traditional classroom teaching. It encourages students to develop self-regulated learning skills, enabling them to take more control over their education. The blended learning environments have gradually gained popularity across various educational settings, from K-12 schools to higher education institutions and professional development programs (Dziuban et al., 2018; Nácher et al., 2021).

The effectiveness of blended learning environments depends on whether they can promote deep learning. Previous research has demonstrated that blended learning can facilitate deeper cognitive processing, but this requires carefully designed instructional plans, interactive pedagogies, and continuous feedback loops (Jiang et al., 2024; Stone et al., 2022). Advancing blended learning toward deep learning will be an important challenge in the future. Although researchers, both domestically and internationally, are increasingly focused on how to effectively stimulate deep learning in blended learning environments, systematic research on the design, implementation, and evaluation of its effectiveness is still lacking. This indicates that current research has not thoroughly explored how to effectively promote students' deep learning in blended learning environments, particularly in terms of course design, teaching methods, and the use of assessment tools, lacking a unified theoretical framework and practical guidance. A literature review, through systematically reviewing and summarizing existing research, can help the academic community and educational practitioners identify the gaps and shortcomings in current research and recognize the core elements of deep learning in blended learning environments.

Moreover, existing assessment methods mainly focus on superficial evaluations of learning outcomes, neglecting the multidimensional evaluation of cognitive changes, emotional experiences, and students' self-regulated learning abilities in the process of deep learning. Therefore, conducting a literature review can reveal the limitations of the current assessment system and provide theoretical support for designing more comprehensive and precise assessment tools, helping educators understand and evaluate students' deep learning performance from multiple perspectives. The literature review can also guide future research directions and advance theoretical and practical progress.

The findings of this systematic literature review will greatly enrich the knowledge base on the integration of deep learning and blended learning, exploring how these two can be effectively combined in educational practice. By analyzing and summarizing existing research, this review provides the academic community with systematic insights on how to promote deep learning in blended learning environments, while offering valuable guidance to educators and instructional designers to better integrate deep learning concepts with blended learning models in their teaching processes. By clarifying the directions and key areas for future research, this review provides the academic community with a research blueprint for deep learning of students in blended learning environments.

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## RESEARCH OBJECTIVES

This systematic literature review synthesizes and analyzes existing research on students' deep learning in blended learning environments. By reviewing empirical studies, theoretical frameworks, and practical applications, the review aims to:

1. To identify and evaluate the best teaching practices that promote students' deep learning in blended learning environments.
2. To examine how the concept of deep learning is integrated into blended learning environments.
3. To determine the evaluation criteria for students' deep learning in blended learning environments.
4. To compile the data and provide practical recommendations for educators and instructional designers.

## LITERATURE REVIEW

### Deep Learning

Deep learning originated in the mid-1950s with Swedish scholars Marton and Säljö's research on college students' reading strategies. Their research found that learners process learning materials in two primary ways, including deep learning and surface learning. Surface learning emphasizes mechanical memorization and understanding. In contrast, deep learning focuses on applying knowledge in new contexts to make decisions and solve problems (He & Li, 2005). In the field of education, the deep learning approach is often considered in contrast to surface learning and is a new learning concept in the information age. The William and Flora Hewlett Foundation conducted the Deep Learning Study Project (SDL), which broke through cognitive limits and claimed deep learning as a must-possessed capability for students in the 21st century. Their project also proposed a framework that includes cognitive, interpersonal, and personal domains. Eventually, it becomes the guidance for the further development and innovation of deep learning (Asikainen, 2014; Esteban-Guitart & Gee, 2020; Faranda et al., 2021).

### Blended Learning Environments

Blended learning is a teaching method that combines the advantages of traditional face-to-face teaching and e-learning (Delialioglu & Yildirim, 2007). Blended learning environments emphasize the development of critical understanding, information integration, constructive reflection, cognitive transfer, and problem-solving abilities. The goal is to enhance students' deep understanding, guide them from surface learning to deep learning, and elevate their cognitive abilities to higher levels (Zhu, 2016). Studies also claimed that the goal of a blended learning environment is to facilitate students' optimal learning outcomes and help them reach a deep learning level (Zhang & Wang, 2014). Deep learning includes three

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processes: “acquiring information (understanding), developing skills (analysis and reflection), and deep learning (application of problem-solving and innovation).” This aligns closely with the instructional design of a blended learning environment. In this environment, during the pre-class phase, students acquire basic information about key concepts through online resources via smart devices; in the face-to-face classroom phase, they engage in interactive reflection with instructors to build their own knowledge frameworks; finally, in the post-class phase, students apply their learned knowledge to solve real-world problems, thereby internalizing and consolidating knowledge. As a trend in the future of education and learning philosophy, deep learning has driven blended learning to develop on a deeper level.

**Deep Learning in Blended Learning Environments**

An increasing number of researchers are focusing on how to apply deep learning frameworks to the design of blended learning activities. They combine activity theory, the characteristics of blended learning, and the requirements of deep learning to propose targeted activity design strategies, emphasizing the logical sequence and design of activities in the pre-class, in-class, and post-class stages. Li (2019) explored the design of MOOC learning activities from the perspective of deep learning, extracting three main forms of MOOC learning activities—understanding and construction, communication and sharing, and reflection and evaluation—based on grounded theory. Zheng and Guo (2019) proposed that the design of deep learning activities should adhere to four principles: thematic authenticity, goal orientation, learner-centeredness, and a combination of multiple forms, combined with reasonable planning of the learning activity process across pre-class, in-class, and post-class phases. Zhang and Wang (2014) constructed a “3*3 Blended Learning Model” for deep learning, where pre-class activities involve independent learning, critical understanding of acquired information, integration with existing knowledge, and independent construction of knowledge systems. In-class activities facilitate the transfer and application of pre-learned knowledge, contributing to the refinement of knowledge systems. Post-class activities involve teachers assigning reinforcement and extension tasks to pupils to promptly identify and fill learning gaps.

The promotion of blended learning evaluation for deep learning gradually reflects the typical characteristics of diversification in evaluation methods and content. It not only focuses on knowledge acquisition but also progressively incorporates the assessment of skill development, emotional experiences, and other aspects into the evaluation scope (Khong and Tanner, 2024). For instance, under the guidance of deep learning theory, Grover et al. (2015) designed a blended learning course aimed at cultivating advanced computational thinking in high school students. They combined formative quizzes with low difficulty and high frequency, open-ended programming tasks, and comprehensive knowledge transfer tests tailored to subject characteristics to comprehensively assess students’ learning outcomes. A month later, they conducted one-on-one interviews with all students, providing strong evidence of deep learning occurrences. Jiang (2022) conducted specialized research on the evaluation index system for deep learning among university students in a blended learning environment. Applying scientificity, operability, and comprehensiveness principles, Jiang (2022) constructed a four-dimension evaluation index system, including deep learning

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motivation, engagement, strategies, and outcomes. This ultimately resulted in a comprehensive deep learning assessment scale comprising 36 test items (Jiang, 2022).

In addition, evaluation plays a crucial role in assessing the effectiveness of blended learning environments. Traditional evaluation methods are incapable of capturing the complex learning processes and outcomes associated with blended learning. However, the integration of deep learning allows for a more comprehensive evaluation as it can capture diverse learner data and provide meaningful insights into the effectiveness of blended learning (Chen & Zheng, 2022). Furthermore, technology is fully utilized to support learning assessments, enhancing the automation and convenience of evaluations. For instance, the automated evaluation features of online learning platforms can facilitate the assessment of knowledge acquisition. Additionally, it will promote the application of peer assessment, situational assessment, performance assessment, and real-time classroom assessment (Kumar et al., 2021).

## METHODOLOGY

This literature review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) approach proposed by Moher et al. (2010). Essentially, four main phases are included: identification, screening, eligibility, and data analysis. Each phase contributed to narrowing down the relevant literature and ensuring the quality of the selected studies for final analysis.

### Identification

The identification phase started with selecting appropriate keywords related to the deep learning of students in blended learning environments. Subsequently, the keywords were explored using Web of Science (WoS), which is widely recognized as a major source for educational research (Halim et al., 2024; Rams et al., 2024). After identifying all relevant keywords, Table 1 presents the search string that was created to query the WoS. The search string combined terms related to deep learning approaches and blended learning environments. This initial search yielded 366 scholarly papers for the first phase of the systematic review.

Table 1 Search Strings Used in Database Query

| **Database** | **Search String** |
|---|---|
| Web of Science | (“deep learning” OR “deeper learning” OR “deep processing” OR “deep approach” OR “deep strategies” OR “deep learner”) AND (“blended learning” OR “deep learning environments”) |

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**Screening**

The screening phase involved a two-step process to eliminate irrelevant papers. In the first screening stage, duplicate publications were removed, resulting in 362 unique papers. During the second screening stage, the 362 publications were evaluated using specific inclusion and exclusion criteria developed for this study. The main criteria included publication type (research papers and conference proceedings), language (English), publication timeframe (last 25 years, from 2000 to 2024), and WoS Categories (Educational Research and Education Scientific Disciplines). Book chapters, book series, literature reviews, and systematic reviews that did not align with the current research focus were excluded. This screening process resulted in 275 publications being excluded, leaving 87 scholarly articles for the eligibility assessment.

Table 2 Selection Criteria for Literature Review

| **Criterion** | **Inclusion** | **Exclusion** |
| --- | --- | --- |
| WoS Categories | Educational Research, Education Scientific Disciplines | All other categories |
| Language | English | Non-English |
| Timeline | 2000-2024 | Before 2000 |
| Literature type | Journal Articles, Conference Proceedings | Book Chapters, Book Series, Literature Review Papers |
| Publication Stage | Final | In Press |
| Focus | Deep learning in blended environments | General blended learning or deep learning papers without connection |

**Eligibility**

In the eligibility phase, 87 scholarly articles were gathered for detailed assessment. A thorough evaluation of the titles, abstracts, and core contents was conducted to ensure these papers fulfilled the inclusion requirements and aligned with the research objectives. Papers with abstracts out of the review goals or studies not focused on educational contexts were excluded. Additionally, papers that did not address deep learning in blended learning environments were eliminated. After this examination, 58 papers were excluded, leaving 29 scholarly articles for the final analysis. Figure 2 shows the distribution of the number of papers by year.

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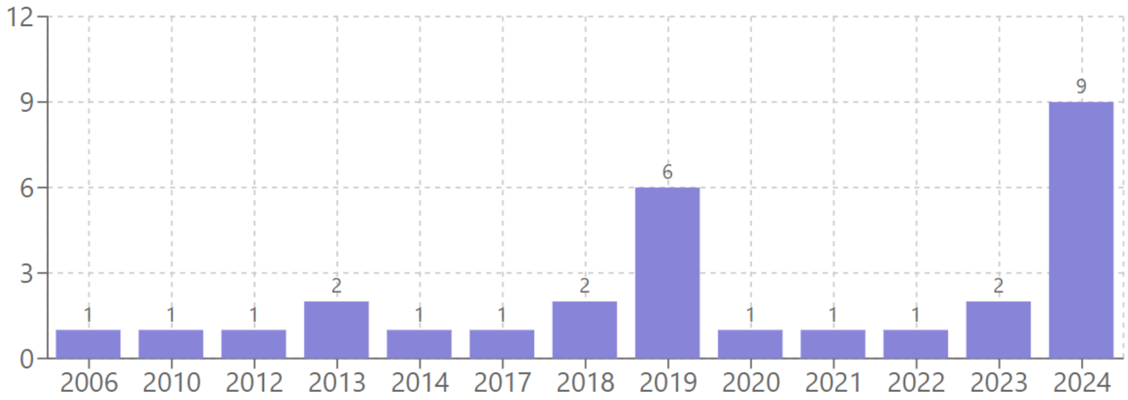
Figure 1 Number of Publications by Year




**Data Abstraction and Analysis**

This study employed an integrative analysis approach that combined several research methodologies. This approach's benefit is that it allows for the examination of qualitative, quantitative, and mixed-methods studies together. Specifically, the analysis focused on identifying relevant themes based on the research objectives across different educational levels and disciplines. The 29 selected publications were carefully reviewed to extract information relevant to the research objectives.

A complete record of the data analysis process, including all findings, issues, and relevant details, is maintained. To ensure theme coherence, regular discussion meetings were held to resolve inconsistencies in the development of the theme. To establish domain effectiveness, the results of the analysis were reviewed by two experts in educational technology and blended learning environments, who assessed the importance, clarity, and applicability of each sub-theme. Professional judgment and feedback are integrated into the analysis during the expert review phase, prompting the research team to make the necessary adjustments, thereby increasing the validity and reliability of the study. The complete PRISMA process implemented in this study is shown in Figure 1.

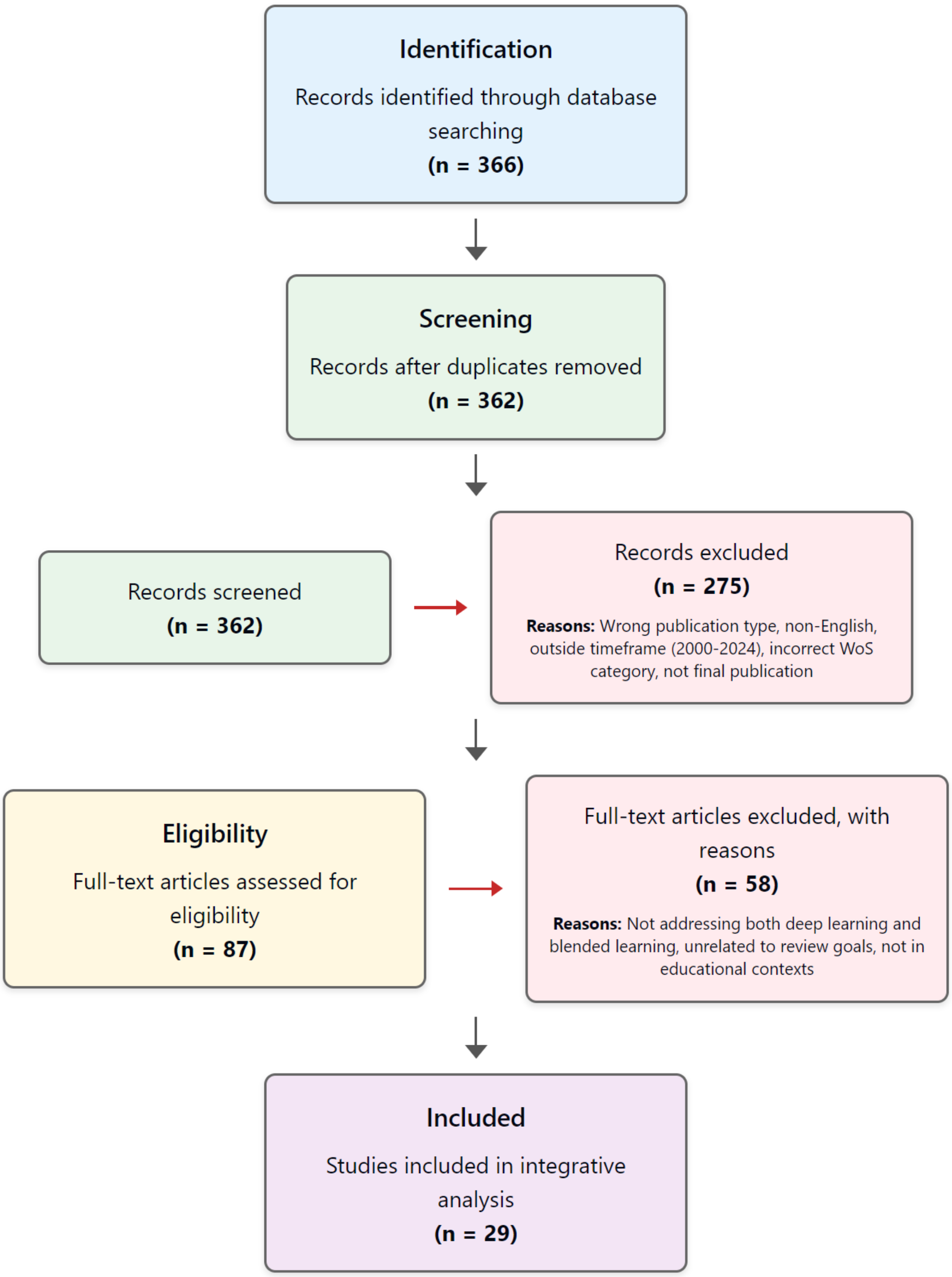



Figure 2 PRISMA Flow Diagram

## RESULTS AND FINDINGS

### Practices for Promoting Deep Learning in Blended Learning Environments

Research on blended learning consistently demonstrates that interactive, student-centered approaches elicit more profound engagement and conceptual understanding. One of the most widely reported strategies is the flipped classroom model, where learners access core instructional materials, such as recorded lectures or assigned readings, prior to class, allowing face-to-face sessions to be dedicated to active problem-solving, discussions, and application-based exercises (Bishop & Verleger, 2013). Zhang et al. (2019) examined a Small Private Online Course (SPOC)-based flipped classroom in an undergraduate physiology course and found that, compared to students in traditional lecture settings, learners in the flipped model achieved significantly higher performance on both pre- and post-tests. This difference was attributed to increased self-regulated learning before class and more constructive in-class peer interactions. However, Zhang et al. (2019) also cautioned that quantitative measures of test outcomes do not fully capture deep learning, calling for additional qualitative measures to investigate whether students genuinely achieved deeper conceptual insights. A strength of Zhang et al. (2019) is its inclusion of both pre- and post-tests to measure change, offering robust comparative insights. Yet a limitation is the lack of in-depth qualitative analysis (e.g., student reflections, interviews) to confirm deep-level conceptual change, which the authors themselves identify as a future research avenue.

Another prominent set of best practices emerges when blended learning incorporates multimodal resources. Stone et al. (2022) conducted a multicenter study on online anatomy education during the COVID-19 pandemic, finding that students granted access to 3D models, cadaveric videos, and interactive discussion forums demonstrated stronger conceptual mastery than those reliant on conventional text-based resources or lecture recordings. These multimodal tools appeared to be especially useful for spatially complex subjects such as anatomy. Nevertheless, Stone et al. (2022) noted that students can feel overwhelmed by the sheer volume of online materials unless instructors provide guidance, scaffolded prompts, and structured pathways to help learners use these tools strategically. While the study's strength lies in its cross-institutional nature—offering a broad participant base and varied contexts—its reliance on self-reported data may introduce bias, and the forced transition to online learning during the pandemic could be a confounding factor. Overall, the authors demonstrate that technology alone does not guarantee deep learning; rather, successful integration depends on alignment with clear pedagogical goals.

Experiential and community-based learning approaches have also proven effective at promoting deep understanding. Pack (2013) studied blended social work courses and found that students working with real-world practice partners were more likely to transfer theoretical concepts into practical skills, displaying heightened critical thinking and ethical awareness. In these instances, the connection between knowledge and practice fostered deeper processing. However, such experiential models hinge on institutional support, strong partnerships with external agencies, and a curriculum that seamlessly merges theoretical instruction with real-life tasks (Pack, 2013). While this design excels at demonstrating how theoretical knowledge can translate into professional competencies, its small sample size in a single discipline (social work) may limit generalizability to other contexts. Similar trends have been documented in humanitarian and professional studies, where field experiences are integrated into online modules or in-class discussions to ensure that students reflect on, and find meaning in, real-world complexities (Stone et al., 2022; Zhang et al., 2019).

Teaching presence and social interaction are crucial dimensions of best practice, as articulated in the Community of Inquiry (CoI) framework (Garrison et al., 2001). Several studies, including Yang and Lay (2024), demonstrate that strong instructor facilitation, coupled with a sense of social presence among peers, can boost students' confidence and willingness to engage in deep cognitive tasks. In Yang and Lay's (2024) inquiry, the authors employ structural equation modeling (SEM) to reveal how academic buoyancy mediates the relationship between teaching, social, and cognitive presences, lending a robust statistical foundation to the CoI claims. Yet the study's limitation is its relatively general sample, which does not differentiate by subject domain or level of content complexity, potentially hindering direct application to disciplines with heavy technical requirements. Similarly, in an online environment that cultivates frequent instructor feedback, structured discourse, and clear expectations, learners report feeling more connected to each other and the material, thereby sustaining deeper engagement (He et al., 2023). However, the single-institution nature of He et al.'s (2023) AI-driven analytics approach means it remains uncertain how well the findings generalize to contexts with fewer technological resources.

The results of the study show that the best teaching practices focus on the application of multiple ways to maximize student interaction, reflection, and problem-solving. These include flipped classrooms, rich multimedia, experiential projects, and supportive guidance from teachers. Future empirical research should explore more deeply the impact of these teaching strategies on students' long-term knowledge retention and practical skills, possibly by comparing different groups or across multiple semesters. Few studies have focused on personality traits (e.g., introversion/extroversion) or the interaction between different motivational patterns and specific best practices. Flipped designs, online discussions, or experiential task studies tailored to the characteristics of different learners are expected to provide detailed guidelines for optimizing the in-depth learning experience in a variety of educational settings.

Figure 3 Relative Strength of Evidence for Each Practice

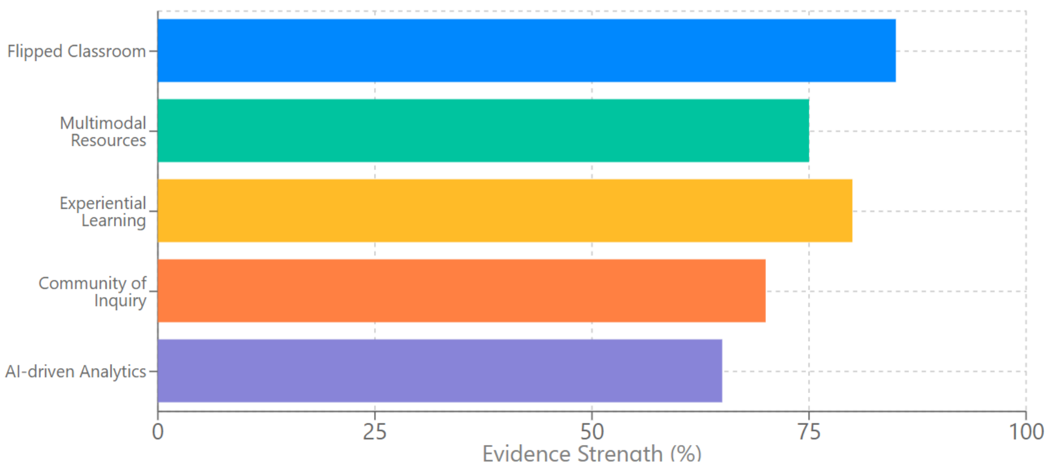



Figure 3 provides an overview and comparison of five key practices for promoting deep learning in blended learning environments identified based on a literature review. The horizontal bar chart shows the strength of research support for each approach, with the flipped classroom model (as shown by Zhang et al. (2019)) receiving the strongest empirical support, followed by experiential learning and multimodal resources. Table 3 provides a comparative analysis of the various practices, highlighting the unique contribution of each approach in promoting student engagement and conceptual understanding. Figure 3 and Table 3 indicate that effective deep learning strategies typically revolve around maximizing interaction, reflection, and applied problem-solving across various educational contexts.

Table 3 Detailed Comparison of Practices in Literature

| Practice | Key Study | Discipline | Key Findings | Limitations |
|---|---|---|---|---|
| Flipped Classroom | Zhang et al. (2019) | Physiology | Higher performance on pre/post-tests; increased self-regulated learning; more constructive peer interactions | Lack of in-depth qualitative analysis to confirm deep-level conceptual change |
| Multimodal Resources | Stone et al. (2022) | Anatomy | Stronger conceptual mastery compared to conventional text-based resources | Reliance on self-reported data; pandemic as confounding factor |
| Experiential Learning | Pack (2013) | Social Work | Better transfer of theoretical concepts to practical skills; heightened critical thinking | Small sample size in a single discipline; limited generalizability |
| Community of Inquiry | Yang & Lay (2024) | General | Academic buoyancy mediates relationship between teaching/social presence and deep learning | General sample without subject domain differentiation |
| AI-driven Analytics | He et al. (2023) | Higher Education | Frequent feedback and structured discourse leads to feeling more connected to material | Single-institution study; may not generalize to contexts with fewer resources |

**Integration of Deep Learning in Blended Learning Environments**

Scholars have devoted substantial attention to how deep learning is operationalized and embedded within the structure of blended courses. One approach is the SPOC-based design that merges the breadth of Massive Open Online Courses (MOOCs) with the intimacy of smaller class sizes, allowing for more personalized feedback (Jiang et al., 2024; Zhang et al., 2019). Jiang et al. (2024) found that vocational college students who participated in a SPOC-based model were more enthusiastic about engaging in pre-class quizzes and reflection tasks, as these tasks primed them for advanced problem-solving activities in face-to-face sessions. This study's strength lies in carefully structuring a sequence of pre-class tasks that linked clearly to in-class discussions, fostering heightened motivation and satisfaction. However, while Jiang et al. (2024) quantitatively demonstrate these gains, they do not deeply explore demographic or cultural variations that might influence how students navigate SPOCs.

Another well-established technique is the flipped classroom, introduced in numerous medical, engineering, and social science programs (Bishop & Verleger, 2013; Di Marco et al., 2017). Di Marco et al. (2017) conducted a quasi-experimental study in medical education, reporting that students in the flipped environments demonstrated superior clinical reasoning skills compared to those in lecture-based settings. They hypothesized that the difference arose because flipping allowed students to approach complex, real-life clinical cases in the classroom, following targeted individual study online. This alignment of asynchronous preparation with synchronous, hands-on practice has been described as the "convergence" of online and face-to-face components (Garrison & Kanuka, 2004; Van Der Stap et al., 2024). Di Marco et al.'s (2017) research benefits from a control group design, offering a more reliable comparison; still, they did not provide extended follow-up to assess whether improved clinical reasoning persisted in advanced courses or professional practice.

Integration also involves scaffolding metacognitive skills throughout the online and offline continuum. Nikolaeva et al. (2019) introduced explicit metacognitive training (e.g., teaching students to reflect on knowledge gaps and strategize their study habits) in vocational blended courses. Learners reported heightened self-awareness, more effective time management, and deeper content mastery. A potential limitation is that the study relied mostly on student self-report, which can be subject to social desirability bias. Still, such findings illustrate that integrating deep learning in blended formats is not just about uploading supplementary resources but ensuring that each digital or in-person session culminates in reflection, discourse, and the construction of conceptual linkages (He et al., 2023).

Universal Design for Learning (UDL) has emerged as another guiding lens for integration. Altowairiki (2024) emphasized that UDL-based blended courses allow for multiple means of representation (text, videos, simulations) and expression (written reflections, multimedia projects), making the learning experience more accessible and often more engaging. This inclusivity can be an impetus for deeper engagement, especially when the course carefully aligns these diverse modalities to well-defined learning outcomes.

Table 4 provides a comparison of the four approaches to integrating deep learning in blended learning environments. While many studies confirm the efficacy of flipped classrooms, SPOCs, and scaffolding, additional comparative research could explore how such strategies fare in large-enrollment undergraduate courses compared to more specialized graduate programs. Moreover, questions remain about the durability of deep learning once students leave the structured environments of a blended course. Longitudinal studies that track learners beyond course completion could reveal how well integrated tasks, like reflective prompts, collaborative case analyses, and scaffolded online modules, translate into advanced studies or professional practice. Finally, investigating how AI-driven adaptive learning tools might further personalize and integrate the deep learning trajectory is another frontier worth examining.

Table 4 Summary of Integration Method

| Integration Approach | Key Study | Key Findings | Strengths | Limitations |
|---|---|---|---|---|
| SPOC-based design | Jiang et al. (2024); Zhang et al. (2019) | Students were more enthusiastic about pre-class quizzes and reflection tasks; Tasks primed students for advanced problem-solving activities in face-to-face sessions | Careful structuring of pre-class tasks; Clear links to in-class discussions; Fostered heightened motivation and satisfaction | Did not deeply explore demographic or cultural variations |
| Flipped Classroom | Bishop & Verleger (2013); Di Marco et al. (2017) | Students in flipped environments demonstrated superior clinical reasoning skills; Alignment of asynchronous preparation with synchronous, hands-on practice | Control group design offering reliable comparison | Did not provide extended follow-up to assess persistence of improved clinical reasoning |
| Metacognitive Skills Scaffolding | Nikolaeva et al. (2019) | Learners reported heightened self-awareness, More effective time management, Deeper content mastery | Focus on construction of conceptual linkages | Relied mostly on student self-report; Potential social desirability bias |
| Universal Design for Learning (UDL) | Altowairiki (2024) | Multiple means of representation (text, videos, simulations); Multiple means of expression (written reflections, multimedia projects); More accessible and engaging learning experience | Inclusivity can be an impetus for deeper engagement | None specifically mentioned |

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**Evaluation Criteria for Students' Deep Learning in Blended Learning Environments**

Evaluating deep learning entails moving beyond surface-level examinations that merely test recall. Scholars increasingly advocate for authentic assessments, iterative feedback, and reflective instruments that probe the depth of students' conceptual understanding (Abdelaziz, 2012; Altowairiki, 2024). For instance, Stone et al. (2022) built reflection prompts directly into 3D anatomy modules, requiring students to articulate why they selected specific learning pathways and how they connected virtual anatomical structures to real-world medical contexts. This approach provided instructors with nuanced snapshots of students' reasoning processes, surpassing the limited feedback from multiple-choice tests. One limitation of the Stone et al. (2022) study, however, is its reliance on self-report data, which may inflate or deflate learners' perceived engagement.

Formative assessments such as essay writing tasks and online quizzes help gauge students' evolving comprehension and identify misunderstandings early (Jiang et al., 2024). Teachers can guide students to deeper inquiry by regularly assessing their learning and providing timely feedback. Peer review sessions and self-assessment scales have been shown to develop metacognitive awareness and critical reflection skills (Ellis et al., 2006; Westerlaken et al., 2019). These practices enable students to learn not only to solve problems but also to evaluate their own solutions with rigor and clarity, reflecting the importance of collaborative and reflective practices in a professional setting.

AI-driven learning analytics is an emerging frontier in evaluating deep learning (Shi et al., 2023). Some platforms track metrics such as time spent on tasks, frequency of online discussion posts, and patterns of resource usage. When analyzed in conjunction with performance data, these metrics can offer early indicators of whether students are adopting superficial or more substantial engagement strategies. Nevertheless, Hyll et al. (2019) caution that analytics alone may not capture the full complexity of deep thinking, particularly for learners who prefer offline note-taking or interpersonal discussions. Their comparative study of digital presentation tools (e.g., Prezi) versus traditional lectures in medical education indicates that raw metrics offer insight into participation but do not necessarily confirm deep-level cognitive processing. Thus, hybrid evaluation models—combining analytics dashboards, reflective journals, and teacher-led observations—are recommended to ensure a well-rounded perspective on deep learning.

Based on the literature review above, Figure 4 presents a comparative analysis of seven assessment approaches used in blended learning environments. The radar visualization illustrates how different methods vary in their relative reported effectiveness, with Authentic Assessments and Hybrid Evaluation methods appearing as strongest, creating prominent extensions in the radar's shape. These are followed closely by reflective Instruments and formative assessments, which excel at capturing students' evolving understanding and metacognitive processes. The chart reveals that more traditional evaluation approaches like peer review occupy a middle position, while technology-dependent methods such as AI-driven ones show promise but have the lowest effectiveness, likely due to limitations in capturing the full complexity of deep thinking. This visualization helps educators understand the relative strengths of different assessment strategies.

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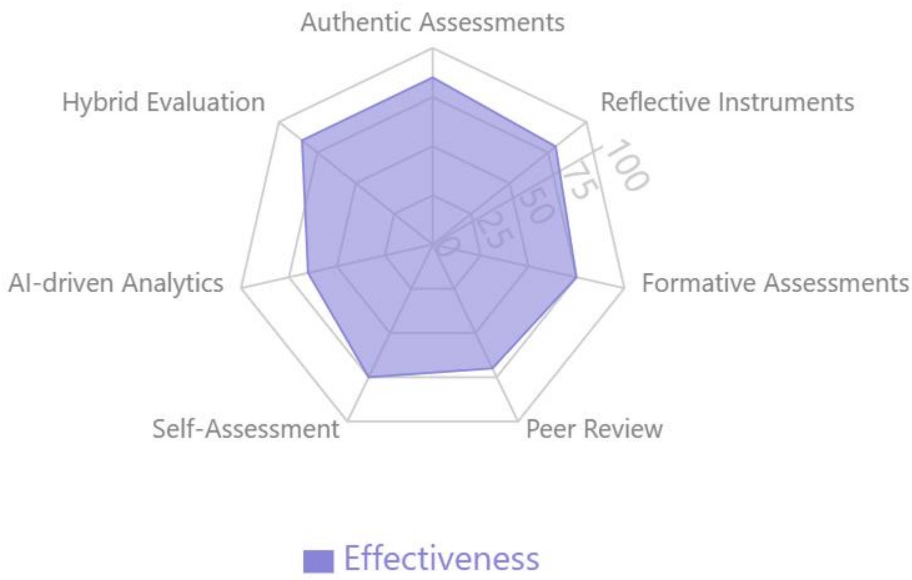
Figure 4 Relative Effectiveness of Evaluation Methods for Assessing Deep Learning in Blended Learning Environments




Researchers in the future could investigate more robust ways to combine AI-driven analytics with in-depth qualitative data (e.g., focus groups or learner diaries) to triangulate evidence of deep learning. Future studies might also explore how to tailor authentic assessment tasks to different cultural or disciplinary contexts, an area still under-examined in the current literature. Additionally, there is a need for longitudinal investigations that track students' deep learning trajectories across multiple semesters, examining how different evaluation strategies sustain or diminish deep learning behaviors over time. A related question concerns how best to help students interpret and respond to feedback from analytics dashboards, ensuring these tools promote deeper reflection rather than superficial "checklist" behaviours.

**Practical Recommendations for Educators and Instructional Designers**

Synthesizing these insights yields several practical steps for cultivating deep learning in blended environments, as summarized in Tables 5 and 6. A primary recommendation is to align online materials and face-to-face tasks so that students continuously build upon their foundational knowledge in offline modules, culminating in higher-order discussions or projects during class (Bishop & Verleger, 2013; Di Marco et al., 2017). Equally critical is the role of scaffolding (Abdelaziz, 2012). Educators should provide explicit cues, like guided notes, prompting questions, or targeted online quizzes, that help students pinpoint knowledge gaps and prepare effectively for more advanced interactions in subsequent sessions.

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Table 5 Practical Recommendations for Educators

| Recommendation | Description | Supporting Research | Implementation Example |
|---|---|---|---|
| Content Alignment | Align online materials with face-to-face tasks for knowledge building | Bishop & Verleger (2013), Di Marco et al. (2017) | Pre-class videos and readings that directly inform in-class case studies and problem-solving sessions |
| Scaffolding | Provide guided notes, prompting questions, and targeted quizzes | Abdelaziz (2012) | Interactive guided notes with embedded questions that help students prepare for synchronous discussions |
| Metacognitive Reflection | Embed reflection prompts in LMS and use think-pair-share activities | He et al. (2023), Nikolaeva et al. (2019), Stone et al. (2022) | Weekly reflection journals where students document their learning process, difficulties, and breakthroughs |
| Technology Integration | Use technology to enhance teacher presence and peer interaction | Garrison et al. (2001), Yang & Lay (2024) | Interactive forums with instructor presence and regular feedback integrated with content delivery |
| Personalized Feedback | Combine digital diagnostics with empathetic instructor facilitation | Howison & Finger (2010) | Combining LMS analytics with personalized video feedback that addresses students' specific challenges |

Metacognitive reflection emerges as a recurring theme. Students who regularly assess their own learning strategies and outcomes—through journals, discussion forums, or structured feedback cycles—tend to exhibit deeper engagement (He et al., 2023; Nikolaeva et al., 2019). Instructional designers can embed reflection prompts throughout a course's LMS environments, prompting learners to comment on difficulties, epiphanies, and connections they make while navigating digital content. In the face-to-face context, educators can further spur reflection by facilitating group discussions or "think-pair-share" exercises that push students to articulate and refine their insights collaboratively (Stone et al., 2022).

Technology should be employed in ways that elevate, rather than overshadow, teacher presence and peer interaction (Garrison et al., 2001; Yang & Lay, 2024). Educators might use AI-based tutoring or quizzes to identify misconceptions early, but they still need to provide humanized feedback that resonates with learners' personal goals or anxieties (Howison &

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Finger, 2010). By combining digital diagnostics with empathetic instructor facilitation, blended courses can maintain a high degree of personalization and responsiveness.

Larger-scale pilot studies that evaluate each “piece” of a blended design—be it the flipped approach, scaffolding elements, or reflection tasks—could help educators figure out which interventions are most effective for different class sizes or disciplines. It may be that a scaffolding-heavy design works best for first-year undergraduates, while advanced graduate seminars benefit more from a peer-led collaborative approach. Cross-institutional collaborations could yield a shared database of best practices, with robust data on how each design element impacts diverse student populations.

Table 6 Contextual Implementation Strategies

| Learning Context | Recommended Approach | Rationale | Example |
|---|---|---|---|
| First-Year Undergraduate | Strong scaffolding with guided reflection | Novice learners benefit from more explicit structure and guidance | Detailed guided notes with embedded self-check quizzes and reflection prompts |
| Advanced Undergraduate | Balanced alignment with metacognitive strategies | Developing autonomy while maintaining some structured support | Pre-class materials with clear connections to in-class problem-based learning activities |
| Graduate Seminars | Peer-led collaborative approaches with technology support | Leverages higher autonomy and professional interests | Student-led discussions based on preparatory materials with embedded reflection points |
| Technical/Scientific Fields | Content alignment with targeted scaffolding | Complex concepts require sequential building and clear connections | Structured online modules that prepare for in-person lab or problem-solving sessions |
| Humanities/Social Sciences | Reflection-heavy with personalized feedback | Interpretive skills benefit from metacognitive approaches | Discussion forums that connect to in-class debates with personalized instructor feedback |

## DISCUSSION AND CONCLUSION

The results of this systematic literature review demonstrate that blended learning holds substantial promises for facilitating deep learning, provided it is enacted with purposeful design and attention to students’ cognitive and affective processes. This literature review finds that effective deep learning practices in blended learning environments depend on several interconnected strategies. For example, student-centered approaches like flipped classrooms enable higher performance by promoting self-regulated learning and rich peer interactions. Multimodal resources (3D models, videos, interactive forums) enhance conceptual mastery, particularly for complex subjects, though instructor guidance remains essential to prevent overwhelm. Experiential learning connects theory to practice, fostering critical thinking and knowledge transfer, while a strong teaching presence and social interaction boost student confidence and engagement. While the emerging tools of learning analytics and AI offer new avenues for early detection of surface engagement, the literature consistently underscores that deep learning arises most reliably in courses that integrate technology with human-centered pedagogy.

As assessment methods evolve, traditional recall tests have gradually shifted toward more authentic assessments, reflection prompts, formative feedback, and AI-driven analytics tools. To effectively implement deep learning, educators should integrate online learning materials with face-to-face classroom activities, provide appropriate scaffolding, and embed metacognitive reflection. At the same time, the integration of technology should be thoughtful (Yanna et al., 2024), and feedback should be personalized based on different learning contexts and disciplines to ensure optimal learning outcomes.

Future directions may involve longitudinal assessments that trace how blended designs influence students' capacities for critical thinking and creative problem-solving over multiple semesters or even years. Researchers could also delve into how learners' distinct personal or cultural contexts shape their responses to flipped classrooms, community-based tasks, or reflection journals. Ultimately, the growing evidence base points to blended learning as a transformative framework when instructors devote careful thought to the alignment of online and offline components, the scaffolding of metacognitive processes, and the thoughtful evaluation of complex learning outcomes. By continuing to refine these practices, educators and instructional designers can harness the full potential of blended environments to cultivate the deep, flexible, and enduring abilities increasingly valued across various educational systems.

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