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Bibliometric Analysis of Blended Learning Research Trends: Integrating Cognitive Load Theory and Retrieval Practice Perspectives

Alfauzan Ramadhanny Simangunsong[1], Wahyu Setyaningrum[2], Elly Arliani[3], Ariyadi Wijaya[4]
[1,2,3,4]Universitas Negeri Yogyakarta

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ABSTRACT

Blended learning has been widely implemented in education, particularly in response to the rapid development of digital learning environments. However, existing studies predominantly focus on implementation practices and general learning outcomes, while neglecting the cognitive mechanisms that underlie learning effectiveness. This study addresses this gap by analyzing research trends, conceptual structures, and existing research gaps in blended learning through the integration of Cognitive Load Theory and retrieval practice. The objective of this study is to map the development of blended learning research and identify the extent to which cognitive principles have been incorporated into instructional design studies. A bibliometric approach was employed using data retrieved from Scopus and Google Scholar databases covering the period 2020–2025. The data were analyzed using VOSviewer to examine keyword co-occurrence networks, thematic clusters, temporal trends, and research density. The results indicate that blended learning research remains fragmented and largely focused on implementation issues, student engagement, and pandemic-related educational contexts. Although there is a growing interest in theoretical perspectives, the integration of Cognitive Load Theory and retrieval-based learning strategies remains limited. Furthermore, cognitive constructs such as prior knowledge activation, working memory management, and retrieval processes are underrepresented in high-density research clusters, indicating a significant research gap in cognitively grounded instructional design. This study highlights the need for a more structured instructional framework that integrates cognitive principles, particularly through pre-learning interventions that enhance retrieval practice and optimize cognitive load management. The findings contribute to the development of a more theory-driven blended learning model aligned with human cognitive architecture.

Corresponding Author:

Alfauzan Ramadhanny Simangunsong
Universitas Negeri Yogyakarta
Email: alfauzanramadhanny.2025@student.uny.ac.id

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1. INTRODUCTION

Blended learning has become one of the most widely adopted instructional approaches in modern education, particularly in response to the rapid acceleration of digital transformation in learning environments. Although this approach is widely implemented, many studies still report that blended learning is often treated as a technical integration of online and offline instruction rather than a systematically designed pedagogical framework. This condition indicates a fundamental research problem, namely the lack of integration between instructional design and cognitive learning mechanisms in blended learning environments [1], [2].

Previous studies have extensively reported that blended learning can improve student engagement, learning outcomes, and flexibility in learning processes. For instance, several empirical studies highlight that blended learning is effective in increasing academic achievement and learner satisfaction in higher education and secondary education contexts [3], [4]. During the COVID-19 pandemic, blended learning was also widely studied as an emergency instructional model that ensured learning continuity. However, most of these studies remain descriptive and technology-oriented, focusing on implementation models, digital platforms, and student perceptions rather than examining the cognitive processes underlying learning effectiveness [5].

From a theoretical perspective, blended learning is grounded in the integration of face-to-face instruction and digital learning environments, with each mode serving a distinct pedagogical function. Face-to-face learning facilitates social interaction, scaffolding, and immediate feedback. In contrast, online learning provides flexibility, repeated access to materials, and individualized learning pathways [6] and [7]. However, recent literature suggests that the effectiveness of blended learning does not depend solely on the proportions of learning modes, but also on how each component aligns with learners' cognitive processes and knowledge-construction mechanisms. In this context, Cognitive Load Theory (CLT) provides a strong theoretical foundation for analyzing learning effectiveness. CLT emphasizes the limited capacity of working memory and the importance of instructional design that minimizes unnecessary cognitive load while optimizing schema construction in long-term memory [8], [9], [10], [11]. In line with Human Cognitive Architecture, learning is understood as an information-processing system in which knowledge is constructed through gradual schema development [11]. Therefore, mismatches between instructional design and cognitive architecture may lead to cognitive overload and ineffective learning outcomes. In addition, retrieval practice has been identified as a powerful cognitive learning strategy that enhances long-term retention by actively reconstructing information from memory rather than passively reviewing it. Retrieval practice strengthens schema accessibility and reduces working memory load during new learning processes [12], [13].

In structured domains such as mathematics and science, retrieval practice is particularly important because conceptual understanding depends on the activation of prerequisite knowledge [7], [14], [15].

Although CLT and retrieval practice are strongly established in cognitive psychology, their integration into blended learning design remains limited. Recent studies

indicate that blended learning research remains dominated by technological innovations, such as learning management systems, artificial intelligence applications, and digital platforms, while neglecting cognitive mechanisms, including prior knowledge activation, working memory regulation, and knowledge assimilation [16].

Furthermore, bibliometric studies show a shift in blended learning research trends from practical implementation toward theoretical approaches; however, cognitive-based instructional design remains underexplored, indicating a clear research gap [17], [18] Based on these gaps, this study proposes a systematic bibliometric analysis to map the development of blended learning research with a specific focus on Cognitive Load Theory and retrieval practice [19], [20], [21], [22]. The study employs a bibliometric approach to identify research trends, conceptual structures, and underexplored thematic areas within the literature. This approach is expected to provide a clearer understanding of how cognitive principles are currently represented in blended learning research and where future developments are needed.

The objective of this study is to analyze trends, intellectual structure, and research gaps in blended learning research by integrating perspectives from Cognitive Load Theory and retrieval practice through bibliometric analysis. The proposed contribution of this study is to strengthen the theoretical foundation of blended learning by shifting its focus from technology-centered design to cognition-centered instructional design. The expected outcome of this research is a more comprehensive understanding of blended learning as a cognitively grounded instructional framework. In practice, the findings are expected to guide educators and instructional designers in developing blended learning environments aligned with human cognitive architecture, thereby improving learning effectiveness, efficiency, and meaningful knowledge construction.

2. METHOD

This study uses a research design in the form of a literature review. A literature review is not only about collecting articles from various journals; it is also a powerful technique for combining research findings to build meta-level evidence and identify areas that need further investigation, an important component of developing theoretical frameworks and conceptual models. The type of literature review used in this study is a bibliometric analysis [23].

This research does not use humans as research subjects; rather, it uses various articles from journals indexed by Google Scholar and Scopus, compiled with Publish or Perish. The search range starts from 2020 to 2025. Based on the results of several searches, 1,200 articles were found that were compiled with the keyword '*blended learning*'. The collected articles are then saved in the form of a ris/ref manager and then entered into the VOSviewer. The device will generate three types of maps. All three maps provide an overview of network visualization, overlays, and density. Network visualization shows how closely related a keyword is to another word. Overlay visualization shows how old or new an article discussing related keywords and other items is. Finally, the density visualization explains how much research has been done on keywords and other items. The steps to search for articles can be seen in Figure 1 below [23] :

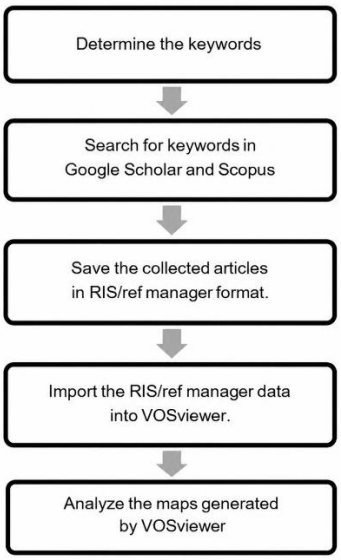

Figure 1. Research Steps

3. RESULTS AND DISCUSSION

3.1. Results

The analysis using *VOSviewer* began with the search for analysis materials with the keyword *blended learning* as the main focus of this final project research. The collection of information about *blended learning* was carried out using the *Publish or Perish 8* application with a range of publications from 2020 to 2025. The results of the analysis using *VOSviewer* are divided into 3 types of visualizations that show the research gap and the novelty of the research to be conducted. The results are shown in the following pictures:

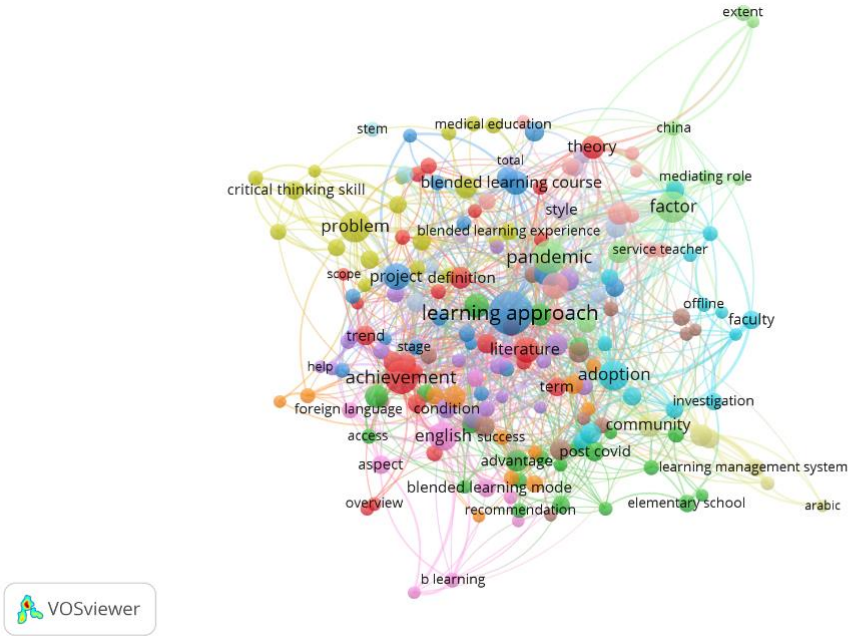

Figure 2. VOSviewer Network Visualization

Based on the image above, network visualization in *bibliometric* analysis using *VOSviewer* has been shown to show how literature reviews on *blended learning* have formed a wide range of study spaces, meaning that many researchers have studied blended *learning*. The networks or clusters in this visualization differ in color. These colors depict a *network of blended learning* research that focuses on various aspects. Some talk about the implementation and driving factors of using *blended learning*, some focus on highlighting learning approaches and acceptance patterns, others focus on general achievements, such as *achievements* and critical thinking skills, and so on. This fragmented visualization provides important information that *blended learning research* has addressed many issues, such as the issue of learning outcomes, but its relationship with the core idea *of blended learning* is still not comprehensive. This shows that the existing research structure has not fully touched on the most basic or fundamental issues in the learning process itself. Furthermore, our discussion enters into a study based on the following VOSviewer analysis images:

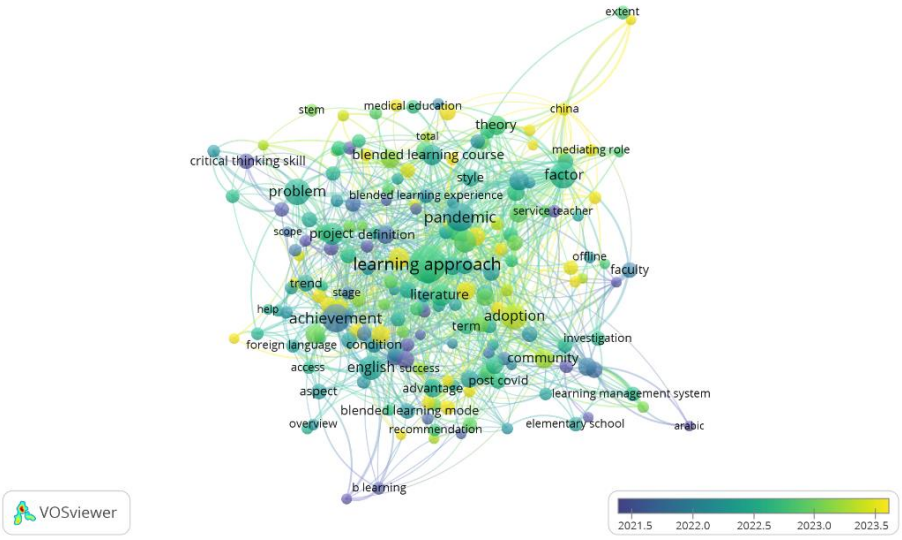

Figure 3. VOSviewer Timeline Overlay Visualization

The image above helps us see how the research focus on *blended learning* has shifted over time. Blue shows studies in the period from 2021 to 2022, while yellow shows more recent research. In the blue part, research is still dominated by responses to pandemics, research keywords such as *pandemic*, *blended learning courses*, and *achievements* are at the center of the picture. This illustrates that in the last five years, *blended learning* has been used more in the online learning process due to the pandemic, which combines online and offline learning. However, when the color began to shift to yellow, the focus of the research shifted to something deeper. Keywords such as *theory* and *mediating role* are starting to appear on the periphery of the map, as if signaling that research is moving from just "what happened during the pandemic" to the question of "what is the concept of *blended learning*" Furthermore, the analysis using *VOSviewer* will focus on the study of the density of *blended learning* research shown in the following figure:

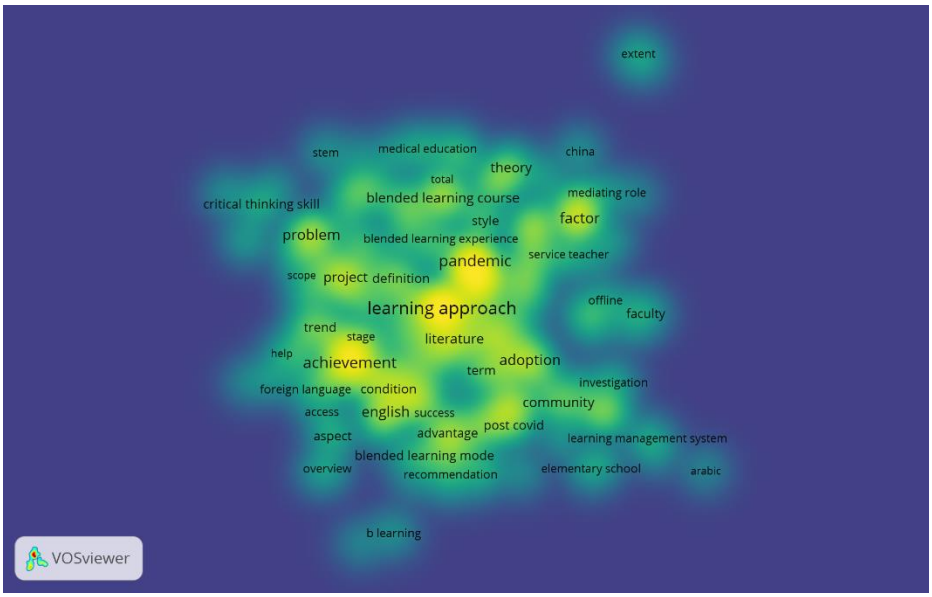

Figure 4. VOSviewer Density Visualization

The image above is an important starting point for understanding the current *blended learning* research map. The bright yellow color indicates the most dense areas discussed by the researchers. At the center, keywords such as *learning approach, pandemic, blended learning course, literature,* and *factor* can be seen. This density shows that in the last five years, *blended learning* research has still moved a lot in the general realm, with more emphasis on how *blended learning* is implemented, what factors affect its success, and how it is used during the pandemic. In other words, most of the research still focuses on documentation and description of implementation, not to mention a more in-depth discussion of digital didactic mechanisms in terms of cognitive theory.

3.2. Discussion

Bibliometric Analysis of Blended Learning Research Trends: Integrating Cognitive Load Theory and Retrieval Practice Perspectives

The results of the network visualization clearly show the conceptual gap that is the basis for the novelty of this dissertation research, because no path or cluster explicitly integrates research on *blended learning* with a digital didactic approach oriented to deep cognitive mechanisms. Such as studies on *retrieval*, assimilation, and *cognitive load*, to *working memory* that limits the mathematics learning process. The keywords that appear are mostly still general and do not indicate the existence of a theoretical framework that deliberately directs *blended learning* to respond to the core problem of how knowledge is built in the mental structure of students. This means that the literature has not provided an answer on how *blended learning* should be modified to be able to overcome the problem of *working memory depletion*, which is actually the main obstacle in mathematics learning. It is at this point that [9] *the Video Retrieval and Assimilation* approach comes as an uncharted mechanism in existing research networks. As a concept that actually shows the untouched innovation space. Thus, this dissertation not only adds new variables to the discussion in

research on blended learning research but also builds theoretical bridges that have not been explored before.

The developed model will link the implementation of *blended learning* oriented to cognitive ability, mathematical literacy, and affective aspects of *math anxiety* through a pre-class mechanism based on *Cognitive Load Theory* [7]. The gap between connections between clusters in the research network provides a strong picture that the *blended learning* model to be developed offers a new direction in understanding how *blended learning* can work more effectively. As a learning model that can help students activate retrieval from before classes start and rearrange their memory structure, its contribution does not stop at the technical level but shifts to a new framework of thinking that is more in line with how human cognitive processes work in the current digital learning era. Furthermore, the visualization of the latest research timeline has begun to talk about *theories,* but the theories that emerge are still very general. There has been no direct study linking *blended learning* with deeper mechanisms of Cognitive Psychology, such as *retrieval practice*, assimilation before class, or design modification based on *Cognitive Load Theory*. It was at this point that the novelty of my dissertation found its footing.

This research is presented in a period with a "yellow" color, following the direction of research that began to look for new theoretical foundations, but went further by bringing in more specific cognitive interventions, namely *Video Retrieval and Assimilation,* to answer real digital didactic problems, namely mathematical literacy [24] and *math anxiety* [25]. Thus, my dissertation will go to the forefront of the development *of blended learning,* where digital learning should be not only technically effective, but also cognitively strong. If you look at it as a whole, the picture above shows that the dissertation I am going to work on is on the right track. Initial studies (blue) have focused on the adoption and application of blended learning. The latest research (yellow) is seeking to identify a truly effective role for intermediaries. This is where the model I offer fills a research gap or missing piece. In this dissertation, I propose a Retrieval and Assimilation mechanism that operates before class starts. By targeting the activation of [8], [12] *prior knowledge* that often causes *extraneous cognitive overload* and triggers *math anxiety*, this study not only adds to the *blended learning literature* but also provides a new direction for digital didactics.

Next, the density visualization appears in blue or purple areas, which are the parts that have low density. This is where the research gap lies. The main keywords that became the foundation of my research were *retrieval practice, assimilation, cognitive load theory, math anxiety*, and mathematical literacy. The discussion of *blended learning* that touches on these aspects does not appear to be at the center of research density. This condition shows that although *blended learning* has been extensively researched, its relationship with the more specific mechanisms of Cognitive Psychology has not been really touched. The focus of research still tends to be on technical aspects and general implementation, rather than on interventions that are theoretically able to explain the root causes of problems such as *inactive prior knowledge*, high *extraneous cognitive load*, and mathematical anxiety that hinders learning. Therefore, there needs to be research that strategically positions itself in these low-density areas, making them spaces of novelty. The research in question needs to

offer a modification of *blended learning* that does not simply combine online and offline learning, but instead departs from a digital didactic framework grounded in cognitive theory.

The low density of research on the aspect of cognitive psychology shows that the solution to the failure of initial schema activation in mathematics learning has not been found in the conventional *blended learning* model. By developing *the Video Retrieval and Assimilation mechanism* in the pre-class phase, this dissertation fills in the theoretical gap left by research that focuses too much on the implementation of the technology. This model is expected to provide a new direction for Digital Didactics while offering solutions better aligned with students' cognitive and psychological needs in today's digital learning.

4. CONCLUSION

This study provides a comprehensive bibliometric overview of blended learning research using VOSviewer to identify conceptual structures, thematic trends, and existing research gaps within the framework of Digital Didacticism. The main finding indicates that the current body of literature remains dominated by general, descriptive studies of blended learning, which are largely reactive to the COVID-19 pandemic and primarily emphasize implementation, technological adoption, and learner perceptions. In contrast, cognitively grounded instructional approaches that integrate Cognitive Load Theory and retrieval-based learning strategies remain underdeveloped and are not yet established as significant thematic clusters in the research landscape.

The findings imply that blended learning research is still in a transitional phase from technology-centered approaches toward cognition-centered instructional design. This highlights the urgent need to reposition blended learning not merely as a digital integration model, but as a pedagogical framework that is grounded in human cognitive architecture. In this sense, Digital Didacticism offers a potential direction for strengthening the theoretical foundation of blended learning by aligning instructional design with cognitive processes such as working memory management and knowledge retrieval. The scope of this study is limited to bibliometric data derived from Scopus and Google Scholar within the 2020–2025 publication period. Therefore, the findings reflect global publication trends but do not include in-depth empirical validation at the classroom or experimental level. In addition, the analysis focuses on keyword co-occurrence and thematic mapping, which may not fully capture the depth of methodological and contextual variations across individual studies.

Future research is recommended to move beyond mapping studies and focus on empirical and experimental investigations that test cognitive-based blended learning models, particularly those integrating retrieval practice and Cognitive Load Theory in instructional design. Subsequent studies should also explore the role of pre-class cognitive activation strategies, including video-based retrieval interventions, in reducing cognitive overload and improving mathematical literacy while addressing learners' math anxiety. In practice, this study contributes to educators and instructional designers by providing a conceptual foundation for developing more cognitively aligned blended learning environments that support deeper learning, reduce cognitive strain, and improve conceptual understanding.

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