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Cognitive Load Theory: A Bibliometric Study over a Decade and Pedagogical Implications

Danlin Yang

College of Foreign Languages, Ocean University of China, Qingdao, China

Abstract: Sweller's cognitive load theory has profoundly influenced educational practices since the 1990s. This paper offers a concise introduction to cognitive load theory and presents an analysis of the current state of domestic research on this topic from 2013 to 2022, using the Web of Science Core Collection and the bibliometric software CiteSpace. Looking ahead, cognitive load theory holds the potential to underpin the design of instructional strategies in second language learning for Chinese English learners, thereby improving the efficiency of classroom teaching.

Keywords: Cognitive Load Theory; CiteSpace; English Class; Pedagogical Implications.

1. Introduction

The concept of human information processing capacity gained increasing attention following the publication of Miller's seminal work in 1956 *The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information* [1]. This paper is regarded as a theoretical cornerstone of modern information processing psychology. Building upon the research of Miller and his colleagues, John Sweller proposed the Cognitive Load Theory (CLT) in the 1980s, which can be traced back to the 1982 publication by Sweller & Levine, *Effects of Goal Specificity on Means-Ends Analysis and Learning* [2], followed by the most widely recognized article *Cognitive Load During Problem Solving: Effects on Learning* in 1988 [3]. Over the following decade, only a few scholars investigated CLT, but their findings significantly enriched the theory. It was not until 1998 that Sweller published the landmark paper *Cognitive Architecture and Instructional Design*, which extended CLT into the field of education and marked a milestone in the history of CLT research [4]. This paper will focus on the developments in the field of CLT after 1998, employing bibliometric software CiteSpace to conduct a visual analysis of literature published in core WOS journals between 2013 and 2022. The analysis will highlight research trends, predict future developments, and summarize the latest advancements in international academic research.

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2. What is Cognitive Load Theory

Cognitive load can be conceptualized as the “mental energy” required to process a given amount of information (Cooper, 1990) [5]. Building on this concept, Sweller introduced CLT in the 1980s as an instructional design framework based on several uncontroversial aspects of human cognitive architecture (Sweller et al., 2019) [6]. The basic idea of CLT is that working memory has a limited cognitive capacity, and when a learning task exceeds this capacity, learning is impeded (de Jong, 2010) [7]. In other words, cognitive load increases when unnecessary demands are imposed on the cognitive system; when this load becomes excessive, it hampers both learning and transfer (Sweller et al., 2019) [6]. According to Diao, Chandler, and Sweller (2007), cognitive load can be understood in three dimensions: mental load, mental effort, and performance of a participant [8].

2.1. Types of Cognitive Load

Cognitive Load Theory identifies three distinct types of cognitive load: intrinsic, extraneous, and germane (Sweller, 2010; Sweller et al., 1998) [4,9]. These types of cognitive load are generally considered additive, meaning that the total cognitive load is the sum of intrinsic, extraneous, and germane loads. Cognitive overload occurs when this total cognitive load exceeds the learner's working memory capacity (Gerjets, Scheiter, & Cierniak, 2009) [10].

3. A Bibliometric Analysis Using Citespace

This study employs CiteSpace 6.2.R2 to visualize the annual distribution of publications, as well as the keyword co-occurrence and clustering network maps, to track the research hotspots and emerging topics in Cognitive Load Theory over the decade from 2013 to 2022. The corpus for analysis was sourced from the Core Collection of the Web of Science (hereinafter referred to as WoS), using "Cognitive Load Theory" as the search term. The time span was set from 2013 to 2022, with the language restricted to English and the document type limited to research articles. After deduplication and filtering in CiteSpace, a total of 2,826 valid documents were obtained.

The study first using published years to conduct a statistical analysis of the temporal distribution of CLT in international journals from 2013 to 2022. As shown in Figure 1, the number of research articles on Cognitive Load Theory published in SSCI journals has steadily increased over the past decade, with the exception of two years where the number remained stable. From 2013 to 2017, the annual publication count remained below 200. Starting from 2018, the number of publications exceeded 200 and saw a significant surge in 2019, reaching nearly 300, and further rising to 342 in 2022. Overall, the research on Cognitive Load Theory has garnered sustained attention from the academic community over the past decade, with its prominence continuously increasing.

Table 1. Types of Cognitive Load

Load Type	Intrinsic Load	Extraneous Load	Germane Load
Source	The inherent complexity of the material and the prior knowledge of the learner.	The way subject matter is taught. Poorly designed instruction that does not facilitate schema construction and automation.	Well-designed instruction that directly facilitates schema construction and automation
Effect on Learning	Necessary to learning (but potentially harmful if too high, because it can cause cognitive overload)	Harmful because it does not contribute to learning	Helpful because it directly contributes to learning
Example	Answer the questions of TEM-8 reading material. This task might have a high intrinsic load for a novice English-majored student, but would have a low intrinsic load for an expert in English.	The student is required to figure out the answers of reading questions themselves, with minimal guidance from the teacher. This imposes a high cognitive load, but does little to encourage schema construction because the student's attention is focused on answering the questions rather than on understanding the material.	The student is explicitly taught how to answer the questions and given lots of worked examples demonstrating how to do it This imposes a lower cognitive load on the student, enabling them to learn and remember how to answer the question when faced with it again.

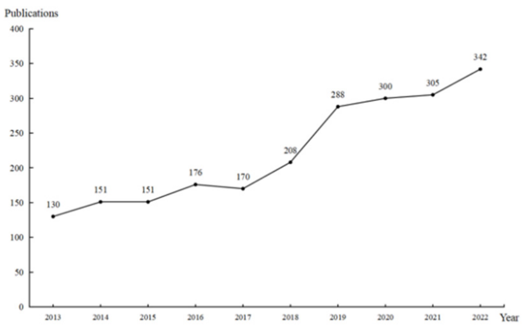

Figure 1. The temporal distribution of CLT researches in international journals (2013–2022)

Secondly, the most frequently co-cited researches are listed in Table 2. This study highlights the top 10 researches that have been co-cited more than 35 times.

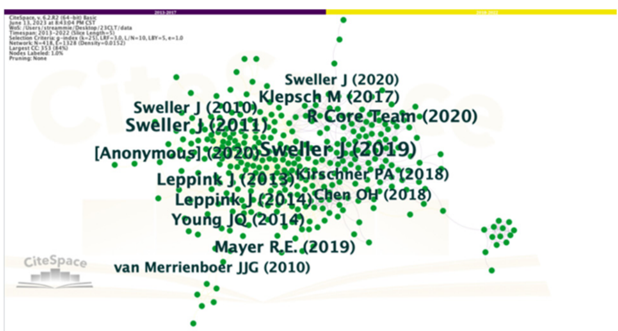

Figure 2. Top 10 Most Co-cited Researches in CLT in International Journals (2013–2022)

Table 2. Top 10 Most Co-cited Researches (2013-2022)

Ranking	Title	Total Frequency of Co-citation
1	Cognitive Architecture and Instructional Design: 20Years Later	122
2	Explorations in the Learning Sciences, Instructional Systems and Performance Technologies	75
3	A Language and Environment for Statistical Computing	61
4	Development of an instrument for measuring different types of cognitive load	53
5	Effects of pairs of problems and examples on task performance and different types of cognitive load	53
6	MULTIMEDIA LEARNING Third Edition	48
7	Development and validation of two instruments measuring intrinsic, extraneous, and germane cognitive load	47
8	Cognitive load theory: implications for medical education: AMEE Guide No. 86	46
9	Element interactivity and intrinsic, extraneous, and germane cognitive load	42
10	MULTIMEDIA LEARNING Second Edition	35

Additionally, a keyword co-occurrence network analysis was conducted on international research related to Cognitive Load Theory. The node type was set to “Keyword,” with the analysis covering the period from 2013 to 2022 and divided into three-year time slices. The resulting network comprised 497 nodes and 2,848 links (see Figure 3). In this network, the nodes represent keywords, with their size corresponding to the frequency of the keyword’s occurrence—the larger the node, the higher the frequency. The links between nodes indicate connections between keywords, and the color gradients within the nodes’ rings represent the different years of occurrence. Table 3 ranks the keywords that appeared more than 105 times in international Cognitive Load Theory research based on their frequency. As shown in Table 3, aside from the search term “cognitive load theory,” the core keywords in international Cognitive Load Theory research include cognitive load, performance, design, working memory, information, instructional design, students, models, knowledge, attention, impact, individual differences, strategies, and memory.

By combining the information in Table 3 and Figure 3, the following characteristics of the research in this field can be observed: 1) Research on Cognitive Load Theory is closely intertwined with the field of education, particularly in instructional design. The literature also reveals that this area of research is most prominent in secondary education instructional design; 2) The research content is diverse, covering topics such as individual differences, individual performance, working memory, and attention.

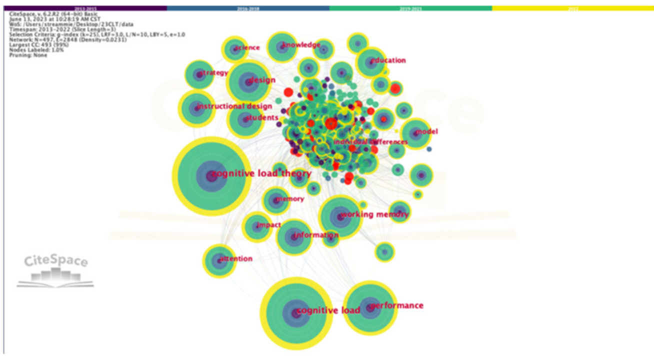

Figure 3. Keywords Co-occurrence network in CLT in international journals (2013–2022)

Table 3. Top 10 High-frequency Keywords in CLT Researches (2013-2022)

Ranking	Keywords	Count
1	Cognitive Load Theory	122
2	Cognitive Load	75
3	Performance	61
4	Design	53
5	Working Memory	53
6	Information	48
7	Instructional Design	47
8	Student	46
9	Model	42
10	Knowledge	35

The cluster analysis was conducted to identify the most significant hot spots in the present distribution of CLT research based on keywords co-occurrence. This analysis also resulted in the generation of a keyword clustering network mapping, as shown in Figure 3. Each cluster may be considered as a distinct study domain, and a bigger cluster size signifies that the cluster has more nodes, indicating a greater level of scholarly interest in the research topics inside the domain. After small and scattered clusters were automatically eliminated, Figure 3 shows several important clusters under the cognitive load theory keyword search. Among them, Cluster 0 is the largest, Cluster 11 is the smallest, Cluster Modularity Q is 0.443, which is greater than the threshold of 0.3, and Cluster Weighted Mean Silhouette S is 0.7446, which is greater than the threshold of 0.7. The above data illustrate that the generated clusters are significant in structure, and the clusters have high confidence (Jie Li, Chaomei Chen 2016) [11].

4. CLT and Pedagogical Implications

The aim of cognitive load research is to develop instructional strategies and recommendations that align with the characteristics of working memory, thereby optimizing learning outcomes. Cognitive Load Theory has generated a variety of pedagogical approaches that can be implemented in educational settings. To illustrate how educators can apply evidence-based cognitive load research to improve student outcomes, several of these strategies are discussed below.

4.1. The Worked Example Effect

A problem that has been previously solved for the student, with each step meticulously explained and demonstrated, is referred to as a “worked example.” The “worked example effect,” a widely recognized phenomenon, suggests that novice learners who study worked examples tend to perform better on subsequent assessments than those who are required to solve the same problems independently (Sweller & Cooper, 1985) [12]. According to CLT, this occurs because unguided problem-solving imposes a heavy load on working memory, which prevents the learner's ability to store information into long-term memory [13]. While the student may successfully solve the problem, the overload on their working memory may prevent them from identifying and retaining the rule that would enable them to efficiently solve similar problems in the future.

4.2. The Expertise Reversal Effect

One significant exception to the worked example effect is the “expertise reversal effect”. The expertise reversal effect states that the frequent use of worked examples loses its effectiveness as learners' expertise rises and eventually becomes unnecessary or even detrimental to learning results (Leslie et al. 2012; Yeung et al. 1998) [14,15]. This indicates that some instructional techniques, such worked examples, which facilitate learning for novices by reducing cognitive load, are ineffective for instructing more experienced students. While the cognitive load hypothesis advocates for fully directed instruction for beginning students, it also advocates for the gradual introduction of more independent problem-solving tasks as students advance in skill.

4.3. The Redundancy Effect

Students do not learn effectively when their limited working memory is directed to unnecessary or redundant information. The “redundancy effect” occurs when learners are presented with additional information that is not directly relevant to learning, or with the same information in multiple forms. An example is a textbook which includes both text and a diagram that needlessly repeat information, or a PowerPoint presentation in which the presenter reads the text presented on the screen. Requiring learners to process redundant information inhibits learning because it overloads working memory. Cognitive load research shows that best practice is to remove redundant information from learning material (Chandler & Sweller 1991; Mayer et al 1996; Torcasio & Sweller 2010)[16–18].

4.4. The Split Attention Effect

The "split attention effect" occurs when learners are required to process two or more sources of information simultaneously in order to understand the material. This might occur, for example, when a diagram is used to explain a concept, but it cannot be understood without referring to a separate piece of explanatory text. In this instance the learner is required to hold both sources of information in their working memory at the same time and to mentally integrate the two. This places a high cognitive load on the working memory, interfering with the ability of the learner to transfer the relevant information to their long-term memory. The split-attention effect can be minimized or eliminated by physically integrating separate sources of information so that they do not have to be mentally integrated by the learner (Cerpa et al. 1996; Owens & Sweller 2008; Ward & Sweller 1990)[19–21].

4.5. The Modality Effect

The "modality effect" is associated with the split attention effect, but offers an alternative technique to reduce cognitive load than physically integrating separate sources of information. Instead, it is also possible to decrease extraneous load on working memory by using more than one mode of communication – both visual and auditory. Evidence suggests that working memory can be subdivided into auditory and visual streams (Baddeley 1983, 2002; Baddeley & Hitch 1974)[22,23], so presenting information using both auditory and visual working memory can increase working memory capacity (Penney 1989)[24]. For example, when using a diagram and text to explain a concept, the written text can be communicated in spoken form. Using both auditory and visual channels increase the capacity of working memory, and facilitates more effective learning (Jeung, et al. 1997; Mousavi et al. 1995; Tindall-Ford et al. 1997)[25–27].

5. Conclusion

Cognitive load theory is a theoretical framework that explains the process by which the human brain acquires and retains information. The theory is substantiated by a substantial amount of classroom evidence and has noteworthy ramifications for teaching methodology. Evidence from cognitive load studies indicates that instructional approaches are most efficient when they have been modified to align with the established boundaries of working memory. Consequently, guided models of instruction are strongly endorsed. Cognitive load theory provides a body of empirically supported suggestions for instructional practice, particularly for instructing inexperienced students in certain subjects such as mathematics, physics, and technology.

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