What is New in Metacognition Research? Answers from Current Literature

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Abstract

Metacognition has become a key element in learning processes. Its advantages include increasing awareness of one's cognitive processes and promoting autonomous, critical, reflective, self-regulated, and self-directed learning. Given its increasing relevance in the academic and scientific community in recent years, this article maps the evolution of metacognition using the tree metaphor to establish the main research approaches emerging today. Through a network analysis of publications in WoS and Scopus and using tools such as Bibliometrix, ToS, and Gephi, the main documents, authors, countries, journals, and fundamental lines of work in metacognition research were identified: evaluation of metacognition in children, metacognition in student education, self-regulation skills, and metacognition in mathematical performance. The results suggest that the development of metacognitive skills has migrated to specific fields such as chemistry, mathematics, and arithmetic, with the latter two showing the most progress in implementing these practices to improve learning outcomes. Additionally, the findings highlight that while teachers consider metacognition necessary for their students' learning, they do not always have the knowledge and skills to teach and apply it effectively.

Keywords (Source: Unesco Thesaurus)

Metacognition; self-regulation; learning; education; literature review.

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¿Qué novedades hay en la investigación sobre metacognición? Respuestas de acuerdo con la literatura actual

Resumen

La metacognición se ha convertido en un elemento clave en los procesos de aprendizaje gracias a las ventajas que ofrece, como una m conciencia de los propios procesos cognitivos y el fomento del aprendizaje autónomo, crítico, reflexivo, autorregulado y autodirigido. Debido a su relevancia, cada vez mayor en la comunidad académica y científica, este artículo realiza un mapeo científico sobre la metacognición para presentar su evolución utilizando la metáfora del árbol y de esta manera establecer los principales enfoques de investigación que surgen en la actualidad. Mediante un análisis en red de las publicaciones registradas en WoS y Scopus, y usando herramientas como Bibliometrix, ToS y Gephi, se identificaron los principales documentos, autores, países, revistas, y las líneas fundamentales de trabajo en las que se enmarca la investigación sobre metacognición: la evaluación de la metacognición en los niños, la metacognición en la educación de los alumnos, las habilidades de autorregulación y la metacognición en el desempeño matemático. Los resultados sugieren que el desarrollo de las habilidades metacognitivas ha migrado a campos específicos como la química, las matemáticas, y la aritmética; estos últimos registran un mayor avance en la aplicación de este tipo de prácticas para mejorar los resultados de aprendizaje. Asimismo, los hallazgos pusieron en evidencia que, aunque los profesores consideran la metacognición importante para el aprendizaje de sus estudiantes, no siempre tienen el conocimiento y las habilidades necesarias para enseñarla y aplicarla con efectividad.

Palabras clave (Fuente: tesauro de la Unesco)

Metacognición; autorregulación; aprendizaje; educación; revisión de literatura.

O que há de novo na pesquisa sobre metacognição? Respostas de acordo com a literatura atual

Resumo

A metacognição tornou-se um elemento-chave nos processos de aprendizagem devido às vantagens que oferece, como a consciência dos próprios processos cognitivos e a promoção da aprendizagem autônoma, crítica, reflexiva, autorregulada e autodirigida. Tendo em vista sua crescente relevância na comunidade acadêmica e científica, este artigo faz um mapeamento científico da metacognição para apresentar sua evolução usando a metáfora da árvore e, dessa forma, estabelecer as principais abordagens de pesquisa que estão surgindo no campo da metacognição. Por meio de uma análise de rede de publicações registradas no WoS e no Scopus, e usando ferramentas como ferramentas como Bibliometrix, ToS e Gephi, identificamos os principais documentos, autores, países, periódicos e linhas de pesquisa sobre metacognição: a avaliação da metacognição em crianças, a metacognição na educação dos alunos, as habilidades de autorregulação e a metacognição no desempenho matemático. Os resultados sugerem que o desenvolvimento de habilidades metacognitivas tenha migrado para campos específicos, como química, matemática e aritmética, sendo que estes últimos registraram maior progresso na aplicação desse tipo de prática para melhorar os resultados da aprendizagem. Além disso, os achados revelaram que, embora os professores considerem a metacognição importante para o aprendizado de seus alunos, eles nem sempre têm o conhecimento e as habilidades para ensiná-la e aplicá-la de forma eficaz. de forma eficaz.

Palavbras-chave (Fonte: thesaurus da Unesco)

Metacognição; autorregulação; aprendizado; educação; revisão da literatura.

Introduction

The outbreak of the COVID-19 pandemic in 2020 caught the world off guard. Education has undergone major transformations (Aldana et al., 2020), posing unexpected challenges to traditional teaching methods (Jiang & Yu, 2021). This new context created the need to explore different, more innovative, and effective teaching models (Ma & Luo, 2021), mainly based on virtual tools (Çamlıbel-Acar & Eveyik-Aydın, 2022). Teachers were forced to change their pedagogical practices and transform curricula to improve students' experiences (Walwyn & Combrinck, 2021). Thus, metacognition emerges to meet today's world needs since it is called the dominant competence of the 21st century (Drigas & Mitsea, 2020).

Metacognition has been an area of interest in research since Flavell's (1976, 1979) seminal documents. According to Capodieci et al. (2019), metacognition enables individuals to contemplate their abilities and skills necessary for a particular task and select the most appropriate strategies to complete it. It also provides knowledge of when and how to use specific strategies for learning or problem-solving (Zhang et al., 2020) and is widely used to help improve student performance in fields such as science and mathematics (Ohtani & Hisasaka, 2018). At the same time, Byrnes and Miller-Cotto (2016) suggest that metacognition is related to factors that enable or motivate children to learn. Metacognition has been found to have potential in other areas, such as text comprehension, where metacognitive knowledge and skills were related to performance (Baker, 1989).

Previous reviews on metacognition were identified. For instance, Gascoine et al. (2017) did a systematic review on the assessment of metacognition in children, while Lavi et al. (2019) conducted a literature review on the role of metacognition in chemistry education. McDowell (2019) examined empirical studies that investigated the contribution of motivation and metacognition to the development of self-regulated learners in college-level physical science courses. Similarly, Cadamuro et al. (2019) reviewed 14 studies on the relationship between information and communication technologies and presented metacognitive skills and learning outcomes. Casale et al. (2021) analyzed 13 papers relating metacognition, self-regulatory executive function, and technological addictions, and Rivers (2021) reviewed 18 articles combining metacognition with test-enhanced learning.

However, so far, no research has been identified that addresses metacognition using scientific mapping and network analysis techniques to identify the evolution and trends of research in this critical field. Previous reviews have focused on applying metacognition in multiple contexts, whereas this review considers a more general field. Consequently, this research aims to review the existing literature on metacognition using bibliometric and scientific mapping techniques and tools and present research perspectives on the subject.

The topic was first queried in the Scopus and Web of Science (WoS) databases using tools such as R, Bibliometrix, Tos, and Gephi; the results were exported and processed. Afterward, a bibliometric study allowed the classification of the most relevant documents under a tree analogy (roots, trunk, and leaves) for subsequent analysis. Finally, the perspectives used in metacognition research were determined through a co-citation analysis.

This paper has been divided into three parts. The first part deals with the materials and methods for searching, choosing, and processing the articles. The second part explains the development of the research and the findings. Finally, the third part presents the conclusions, limitations, and further research recommendations.

Materials and methods

The first step was a scientific mapping to collect the data from WoS and Scopus by analyzing the bibliometric indicators. The second step was a

network construction and analysis using the documents and bibliographic references obtained in the previous stage. The co-citations were analyzed, and the documents were characterized using the tree analogy (3rd century BC by Porphyry), according to Levy (2002). Finally, the research perspectives were identified and graphed through the Gephi tool (Mathieu et al., 2009).

Previous reviews involving metacognition have methodological limitations, such as the number of documents analyzed and the databases used. For example, McDowell (2019) excluded Scopus, only used 14 articles and concentrated on empirical documents. Lavi et al. (2019) used the journals CERP, JCE, IJSE, JRST, and SE and focused on 17 articles. Gascoine et al. (2017) based their study on AEI, BEI, ERIC, ECO, Psy chArticles, Psy chINFO, and Web of Knowledge. Rivers (2021) only included 18 documents in their study, the same limitation as the work of Casale et al. (2021), which only explored 13. Table 1 below presents the search parameters used in this research.

Table 1. Search parameters

Filters	Database	
	WoS	Scopus
Time restriction	2010-2023 (Search date April 13, 2023)	
Journal type	Any	
Search terms	Title: "metacognition*" AND Article title, abstract, keywords: "education*" or "pedagogy" or "learning"	
Total per database	543	1,021
Duplicates	344	
Total publications	1,220	

Source: Own elaboration.

The records obtained in the databases were contrasted to eliminate duplicate data; in this case, 344 documents were found simultaneously in WoS and Scopus, so they were removed from the full register, reaching 1,220 records.

Step 1: Scientific mapping

Zupic and Čater (2015) recommended using bibliometric methods to conduct a production analysis and scientific mapping. The tool used for this procedure was Bibliometrix (Aria & Cuccurullo, 2017) version 3.1, which is included in the R-Studio software, is free to use and has several features that allow bibliometric studies (Aria et al., 2020). Several studies have employed Bibliometrix (Di Vaio et al., 2021; Duque & Cervantes-Cervantes, 2019; Homolak et al., 2020; Mogollón et al., 2022; Ramos-Enríquez et al., 2021; Restrepo et al., 2023).

Step 2: Network analysis

We used graph theory to determine the connections between the documents and obtain data about the network and its documents (Wallis, 2007; Yang et al., 2016). The obtained records were combined, and their references were extracted from Scopus and WoS, eliminating duplicates. From these documents and their references, a citation network was constructed using R programming.

The Gephi tool is used to analyze the network (Mathieu et al., 2009) because it allows viewing the connections of the documents that comprise this area of knowledge. This tool has been used and validated by other research works for scientific mapping (Buitrago et al., 2019; Donthu et al., 2020; Duque & Oliva, 2022; Ferguson, 2012; Meier, 2020). After preprocessing the data to extract the network of citations, three indicators are calculated, indegree (Wallis, 2007), outdegree (Wallis, 2007), and betweenness (Freeman, 1977). Those indicators show when the document is referenced by others (Zhang & Luo, 2017).

The network arises from the references extracted from the documents by calculating indegree, outdegree, and betweenness. The documents are grouped into three categories through the tree analogy, roots (high indegree), trunk (high betweenness), and leaves (high outdegree) (Robledo et al.,

2022; Valencia-Hernandez et al., 2020). Other research works have used this methodology with valuable results (Castellanos et al., 2022; Clavijo-Tapia et al., 2021; Duque, Meza, et al., 2021; Duque, Trejos, et al., 2021; Hoyos et al., 2022, 2023; Hurtado & Ortiz, 2022; Robledo et al., 2023; Rodríguez et al., 2022).

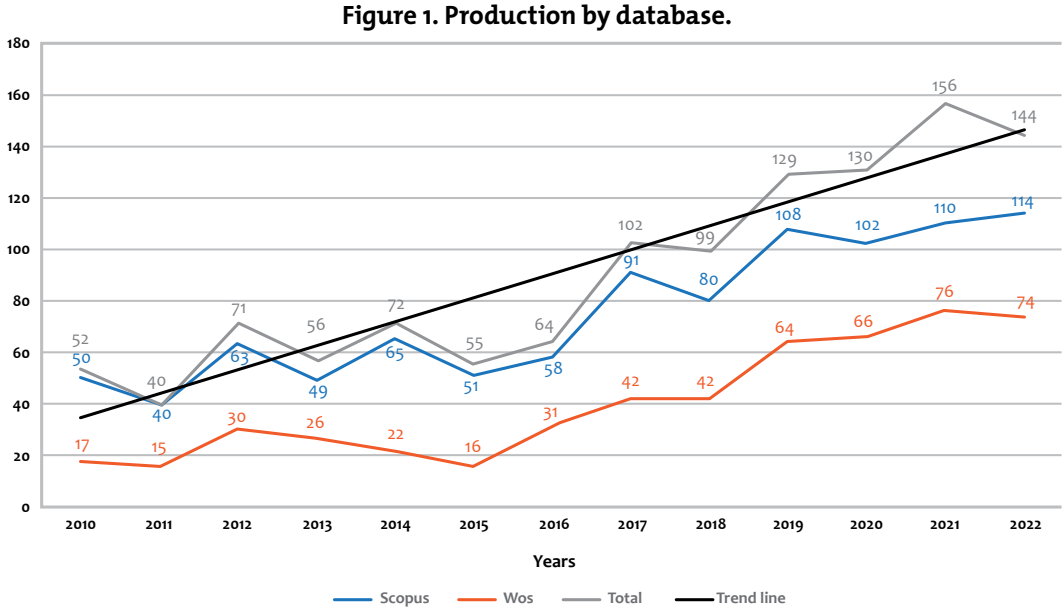
A clustering algorithm proposed by Blondel et al. (2008) was utilized to identify the subareas or perspectives of the topic based on the reference network. This approach allows for the classification of documents into categories through citation analysis. Next, text mining was conducted in R using the WordCloud package (Ohri, 2012). Once these perspectives were identified based on bibliometric criteria, the review was conducted by selecting the 60 most relevant documents, including ten classical (roots), ten structural (trunk), and 40 from each perspective (leaves).

Scientific mapping

Figure 1 represents the scientific production on the topic between 2010 and 2023 in the Scopus and WoS databases (including the total publication calculation from the fusion of the results of both databases and the elimination of duplicate data). An accelerated increase in the number of publications has been observed in recent years, with 609 publications (50% of the total) between 2019 and 2023. Although the field of metacognition has been explored for more than four decades, initiated by authors such as Flavell and Browns, the growing trend in scientific production may indicate the increasing interest of the scientific and academic community. This fact can be corroborated by the positive trend line showing the number of records yearly. Regarding the geographical distribution of publications, the United States occupies a dominant position over other regions, as approximately 40% of the publications come from this country.

Table 2 provides valuable information on the most prolific and impactful authors in the field of metacognition. The data presented highlights the top 10 authors based on the number of publications, citations, and h-index, which indicates their scientific productivity (Hirsch, 2005). The ranking is segmented by database and in total.

Figure 1. Production by database.



Source: Own elaboration.

Paul Henry Lysaker, a scholar at the Indiana University School of Medicine, is the leading contributor in the field of metacognition based on the highest number of publications and citations. Paul Henry Lysaker, a researcher at Indiana University, stands out as the author with the highest number of publications in the field of metacognition and the best impact metrics in this list, which confirms his prominence in this field. Other authors, such as Randy Garrison from the University of Calgary and Roger Azevedo from the University of Central Florida, are notable in metacognition.

Figure 2 lists the top ten scientific journals or sources with the highest publications on metacognition, along with their quartile and impact indicators in each database. The Journal Citation Reports (JCR) are considered for WoS, while for Scopus, the Scimago Journal Rank (SJR) is used. The Journal of Physics Conference Series is the source with the most documents. However, it is not considered a specialized journal on metacognition, as it mainly publishes proceedings of scientific events.

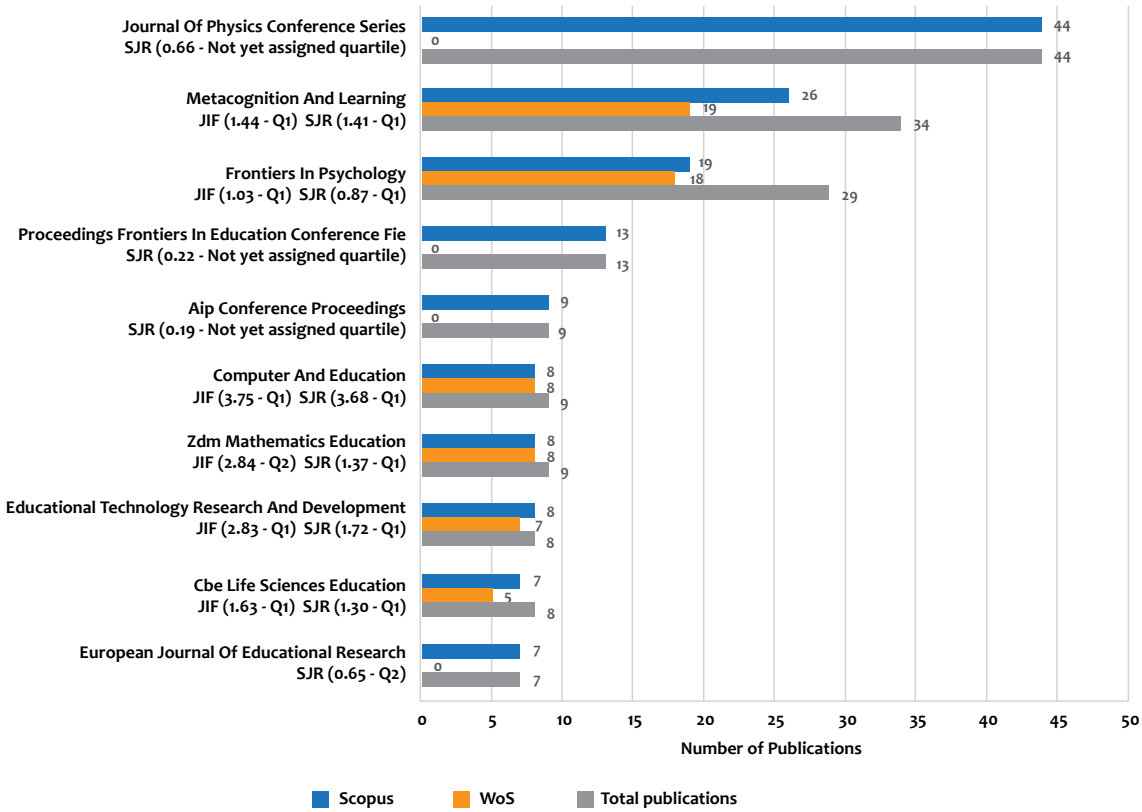
On the other hand, Metacognition and Learning is the second source with the most publications on metacognition. In this case, it is a specialized journal promoting metacognition and learning processes research. Additionally, it is regarded as one of the most important and impactful journals in the field, as it publishes high-quality research papers and theoretical articles related to metacognition, self-regulation, and other related topics.

Table 2. Authors

Author	WoS			Scopus			Total publications
	Number of publications	H-index	Citations	Number of publications	H-index	Citations	Citations
Lysaker, Paul Henry	10	74	19,007	12	78	21,911	14
Efklides, Anastasia	2	22	1,914	7	27	3,036	7
Akyol, Zehra	3	11	849	6	11	1,374	6
Garrison, Randy	4	23	4,124	6	37	12,487	6
Misu, La	2	2	7	6	3	17	6
Whitebread, David	3	20	1,440	6	23	1,890	6
Azevedo, Roger	4	39	6,299	5	46	8,921	5
Buck, Kelly	3	35	3,187	5	38	3,639	5
Desoete, Annemie	5	6	71	5	26	2,053	5
Castel, Alan	5	36	5,176	4	37	5,653	5

Source: Own elaboration.

Figure 2. Relevant journals.



Source: Own elaboration.

Figure 3 links four bibliographic elements. Analyzing the citation network makes it possible to identify the authors with the highest number of citations, an important indicator of their influence and impact in the field (White, 2003). John H. Flavell is the most cited author; he is even considered one of the pioneers of metacognition, along with Gregory Schraw and Ann L. Brown. Other more recent authors whose contribution to the field of study has been recognized by the high impact of their publications are Paul R. Pintrich, Barry J. Zimmerman, and Marcel V. J. Veenman. The work of these authors will be analyzed in the Intellectual base or classical documents section.

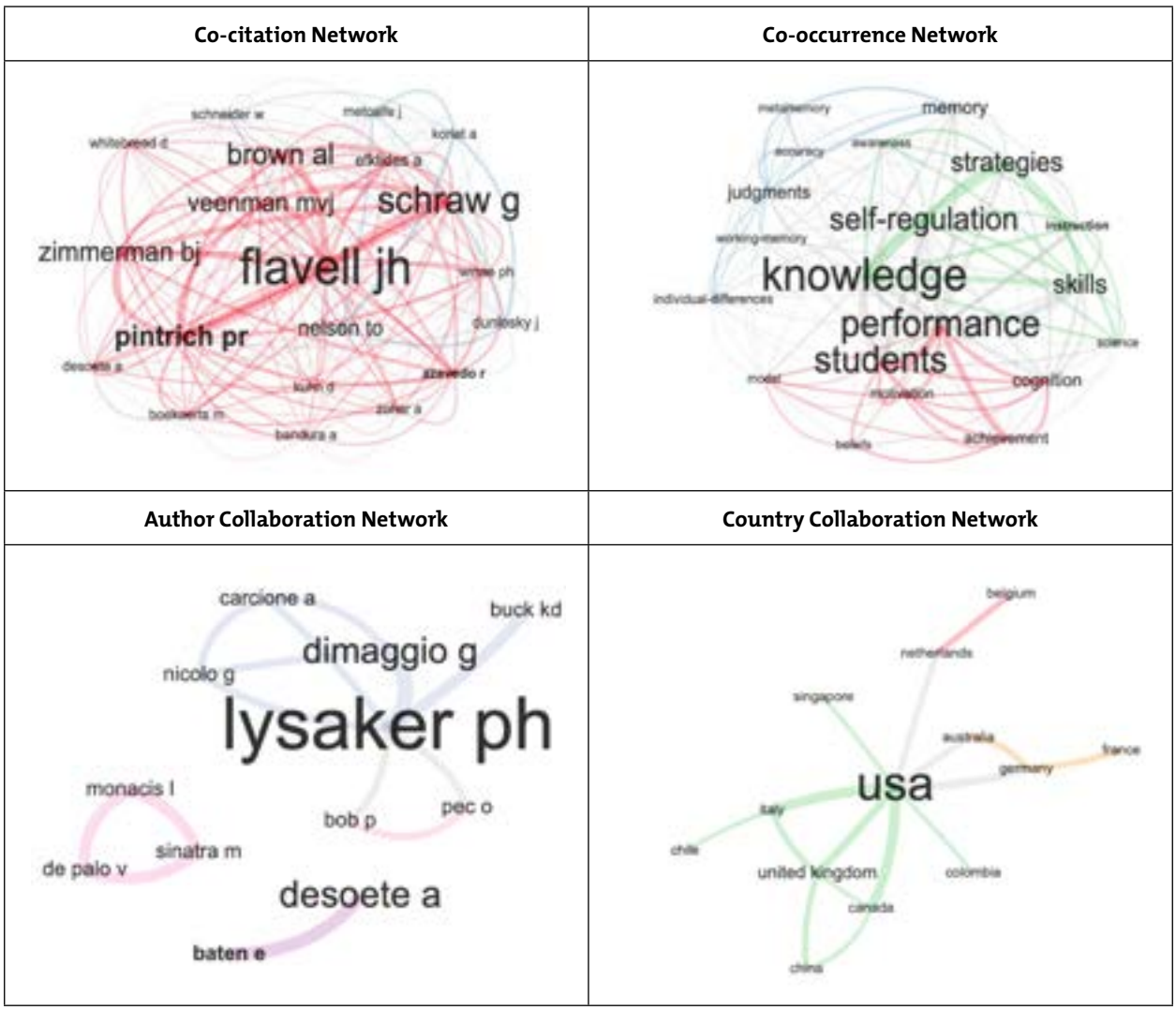
The second element, the word co-occurrence network (interconnection among words), was generated from the KeyWord Plus of each document in the network. The word cloud indicates that knowledge, students, performance, skills, self-regulation, and strategies are the most recurrent terms. In addition, the trend in the emergence of these concepts during the last five years is on the rise, which shows that research in the field is leaning towards these lines. Terms such as cognition and judgments, which were the protagonists at the beginning of the 20th century, have had a downward trend in frequency since 2015.

The third element, the collaboration network among authors, shows close cooperation between Paul Henry Lysaker and Giancarlo G. Dimaggio; these researchers have published four articles in co-authorship. Also, Annemie Desoete and Elke Baten stand out with three co-authored papers. The leading author in production is the same in both databases;

the other authors are also listed, suggesting that collaboration among authors significantly impacts their productivity, as Lee and Bozeman (2005) noted.

Finally, the fourth element shows the network of collaboration among countries. The United States (which is by far the epicenter of publications on the subject) has the most significant number of cooperations, which is reflected in the number and impact of publications. The U.S. connection extends to countries like the United Kingdom, Italy, and Canada. Indiana University, University Indianapolis, and Roudebush VA medical center are considered the main collaborators.

Figure 3. Networks.

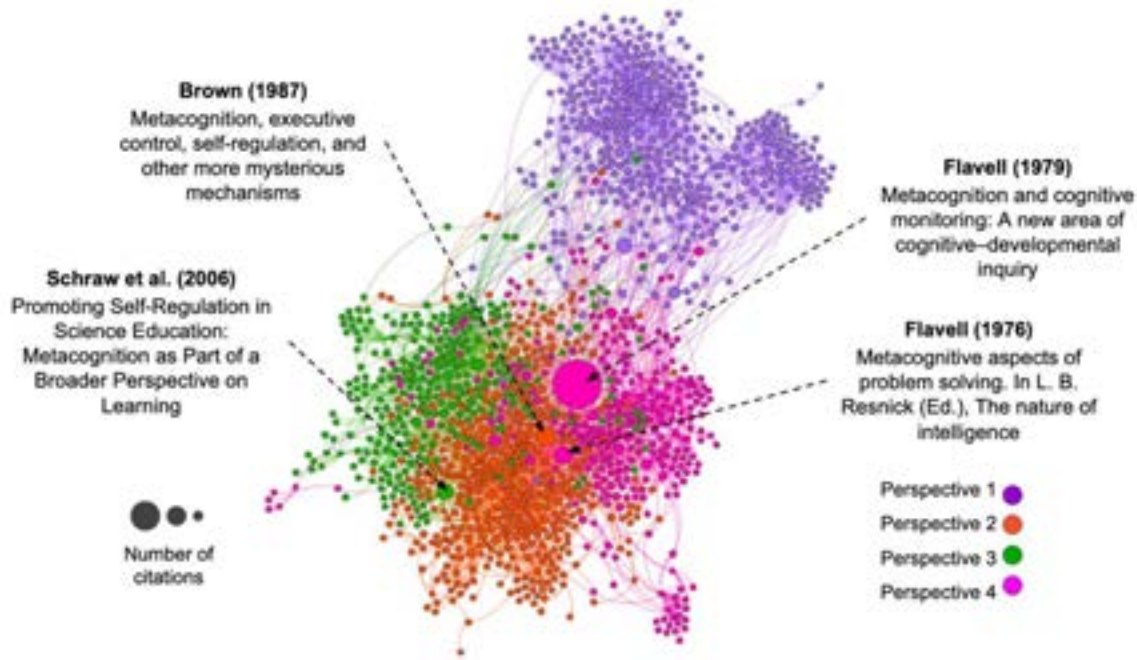


Source: Own elaboration.

Network analysis

The network (Figure 4) comprises 4,664 references and four perspectives (clusters), establishing research currents and trends on the subject under study. Gephi was used for their visualization.

Figure 4. Social network.



Source: Own elaboration.

Four documents are deemed seminal based on the number of times they have been referenced by other documents in the network: "Metacognition and cognitive monitoring: A new area of cognitive-developmental inquiry" by Flavell (1979) (Google citations: 17,695), "Metacognition, executive control, self-regulation, and other more mysterious mechanisms" by Brown (1987), "Metacognitive aspects of problem-solving" by Flavell (1976), and "Promoting self-regulation in science education: Metacognition as part of a broader perspective on learning" by Schraw et al. (2006).

Intellectual base or classical documents (Roots)

Documents considered hegemonic or seminal are the basis of metacognition knowledge. They are frequently cited, which means they have the highest indegree indicator. The ten articles with the highest citation within the network were chosen and analyzed.

This section presents a chronological review of metacognition, its origins and evolution, types of skills, and their role in education. It also shows three critical aspects of metacognition: awareness, self-regulation ability, and classroom application.

Flavell (1976) was the first to introduce the concept of metacognition as the understanding and management of one's cognitive processes. In 1979, Flavell expanded on this concept and proposed a model based on the interplay between metacognitive knowledge, metacognitive experiences, tasks, and strategies, aiming to answer how children and adolescents can develop metacognition. Brown (1987) later contributed to the psy chology of metacognitive thinking by identifying four critical skills: prediction, planning, monitoring, and evaluation.

Through the 1990s, the notion of "metacognition" was further developed and enriched by researchers who focused on different goals. For instance, Nelson (1990) developed a theoretical framework

on metamemory, emphasizing and encouraging the development of specific theories of the role of control and monitoring processes in human memory. Awareness is considered a central concept of metacognition. A tool known as the Metacognitive Awareness Inventory (MAI) was created and validated by Schraw and Dennison (1994) to measure the degree of metacognitive awareness in adults and adolescents. This instrument was designed to assist low-achieving students in improving their academic performance by utilizing appropriate instructional strategies. Schraw and Moshman (1995) reviewed various definitions of metacognition, its origins, and evolution; they reaffirmed the importance of metacognitive theorization from the earliest years of schooling through internal dialogue and interaction to improve and understand one's performance.

In 1998, Schraw listed the following strategies to improve metacognition in the classroom: promoting new general and cognitive knowledge, monitoring cognition, creating supportive and motivational environments, and reflecting upon the instruction of these cognitive skills.

Later, Zimmerman (2000) introduced a social cognitive self-regulation perspective. In this work, he proposed a triadic definition of self-regulation involving the person, behavior, and environment and explored how environmental factors influence self-regulation processes and potential dysfunctions. Pintrich (2002) later emphasized the importance of explicitly teaching metacognitive knowledge to students, emphasizing the need to align classroom objectives, instruction, and assessment.

In response to determining the effects of metacognition on cognition, Veenman and Spaans (2005) experimented with evaluating metacognitive ability and learning performance in first and third-year high school students who solved a math task and a biology questionnaire. The study found that instructing and encouraging young students to develop and use metacognitive skills in various new tasks and domains was highly beneficial, even for poor-performing students. Once developed, these skills were applicable and transferable to other tasks and domains. Finally, Veenman et al. (2006) identified a list of ten future research topics in the seminal documents, including definitions, components, the relationship between metacognition and cognition, conscious versus automatic processes, general versus domain-specificity, developmental processes, assessment, conditions for acquisition and instruction, the connection of metacognition with other individual differences, and neuropsychological research.

Structural documents (Trunk)

The kaleidoscopic view of metacognition given by the classical root documents opened the doors for the articles of this section. The trunk's structural documents give rise to robust applications in the current metacognition research and represent the highest degree of intermediation in the network. High betweenness means that they both cite and are cited by others. The following are the ten most relevant documents in this category:

Georghiades (2004) studied the concept of metacognition in the last thirty years. He concluded that even after this review, the understanding of metacognition remained incomplete and controversial. The author also stressed two needs for the field: the urge to study the impact of reflective thinking explicitly and systematically on young children and the role of policy-making bodies in facilitating teachers' attempts to bring metacognitive thinking to the classroom.

SRL (self-regulated learning) was recurrent in five of the structural documents. Schraw et al. (2006) presented an overview of research on self-regulated learning and recommended six instructional strategies to enhance cognitive, metacognitive, and motivational processes. Dinsmore et al. (2008) cautioned researchers to be mindful of their terminology when

discussing metacognition, self-regulation, and SRL, as these terms may evolve and be used interchangeably. Vrugt and Oort (2008) developed and tested a self-regulated learning model that revealed qualitative differences between effective and less effective self-regulated students. Whitebread et al. (2009) examined the CHILD 3-5 instrument and underscored the significance of precisely describing and measuring metacognitive and self-regulatory skills in young children for theoretical development and educational effectiveness. Lastly, Efklides (2011) proposed the Metacognitive and Affective Self-Regulated Learning Model (MASRL), which regards metacognition, motivation, and affect as SRL components that interact with one another and can aid in understanding the learning process.

Wang (2015) conducted a study to examine the characteristics of metacognition in university students by utilizing four distinct evaluation methods. The study also explored the impact of task characteristics on the deployment of metacognitive skills and how knowledge of the subject matter is differently related to the accuracy of calibration and judgment of confidence. Additionally, in their study, Zepeda et al. (2015) conducted a 30-week action-based experiment with teenagers. They found that metacognitive instruction could improve self-regulated learning outcomes and increase motivation.

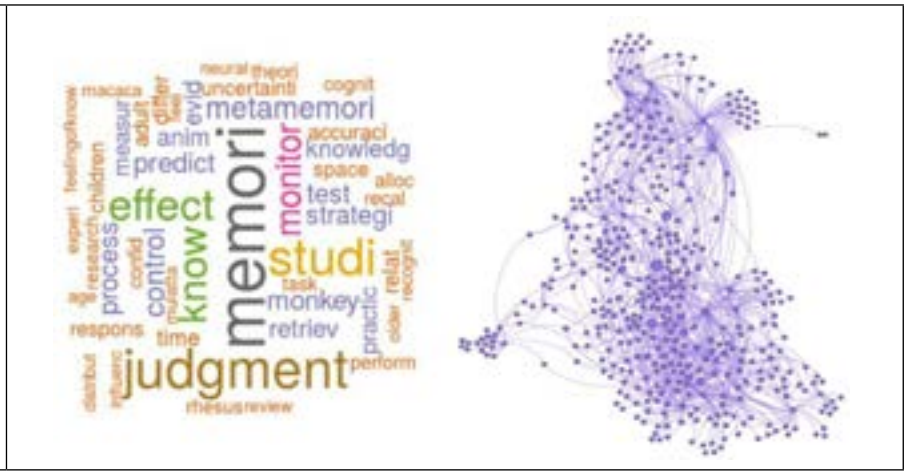
Gascoine et al. (2017) systematically reviewed research between 1992 and 2012 on various methods employed to measure or assess metacognition in children. They reported a link between the definition of metacognition, the assessment used, and the outcomes. Meanwhile, Baten et al. (2017) investigated the effectiveness of metacognition in mathematics teaching and learning, drawing on diverse definitions, conceptualizations, assessment methods, and training models. Their findings supported earlier research and provided additional evidence that metacognition aids in activating prior knowledge, monitoring progress, and thinking before, during, and after learning mathematics.

Perspectives (Leaves)

The following section shows and analyzes the four perspectives identified with the clustering algorithm (Blondel et al., 2008) by reviewing the metacognition papers. Figures 5, 6, 7, and 8 show the word clouds of the central elements that make up the four perspectives identified in this study.

Perspective 1

Figure 5. Perspective 1.

Children's metacognition assessment	

Source: Own elaboration.

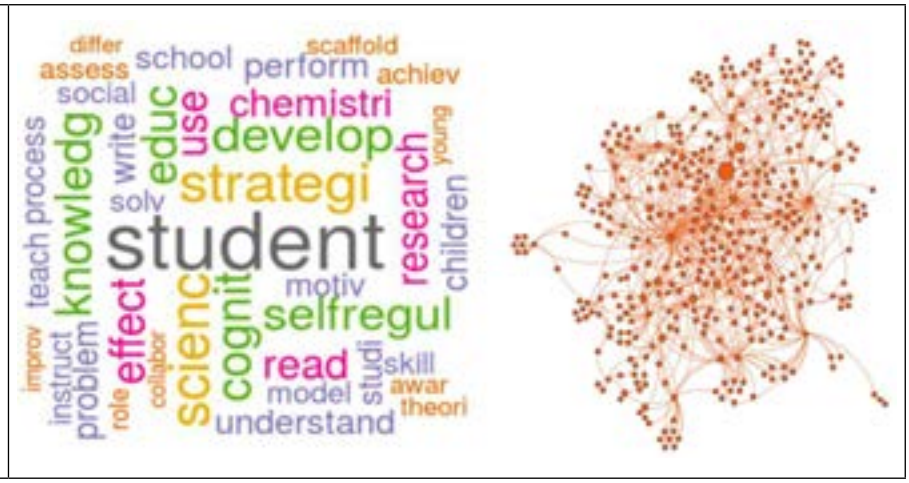
The topic of interest in the metacognitive research community revolves around children. Since 2015, increasing attention has been paid to how metacognition works in young children and how to measure it and address communication difficulties (Coughlin et al., 2015). Several investigations have determined that the development of children's memory, executive functions, and metacognition are all interdependent (Spiess et al., 2016); they also have shown that metacognitive abilities can be observed in infants as young as 12 months old and that properties of metacognition, such as uncertainty, can be reported in 20-month-old children through nonverbal communication (Gliga & Southgate, 2016; Goupil et al., 2016).

Goupil and Kouider (2016) stated that infants possess decision confidence and error-monitoring abilities, but these can only be assessed using nonverbal methods as they cannot explicitly report on themselves. Recent studies suggest that implicit metacognition has a genetic basis in human babies, which provides a foundation for the gradual development of explicit metacognition through experience and learning (Heyes et al., 2020). Because of this, there is a growing trend to use child-friendly, creative, and non-verbal measures to assess and uncover emerging metacognitive abilities in young children, as Roebers et al. (2020) noted.

Investigating interindividual differences in metacognitive abilities and help-seeking behaviors in young children is essential for future research (Goupil et al., 2016). Additionally, there is a need to explore how much metacognitive sensitivity is genetically inherited and the kinds of experiences or training that would enhance metacognitive sensitivity in adulthood (Heyes et al., 2020).

Perspective 2

Figure 6. Perspective 2.

Metacognition in students' education	

Source: Own elaboration.

Metacognition was originally a field of interest in psy chology. However, its proven benefits for effective learning have increased awareness of its significance in pedagogy and education, leading to its gradual integration into classrooms. This perspective highlights some of the latest proposals for incorporating metacognition in education, including eye-tracking, games, apps, and logbooks.

Bowen et al. (2018) suggest that using metacognition in a research-like environment encourages scientific thinking, personal approach development, data analysis, and conclusions based on self-efficacy.

A critical focus for parents and educators is to emphasize the development of both metacognition and self-efficacy levels in students, as this can assist them in completing tasks and providing innovative solutions to problems (Bozgün & Pekdoğan, 2018). Similarly, Colthorpe et al. (2018) note that metacognition can foster lifelong learning skills and adaptability in students. Recent research also aims to improve prospective teachers' metacognition knowledge and awareness. Additionally, a significant relationship exists between metacognitive skills and reading comprehension, influenced by gender and age (Jiménez-Taracido et al., 2019).

Two studies on chemistry education have demonstrated that relating chemistry to everyday phenomena and using an Android chemistry application can increase motivation and metacognition (Lavi et al., 2019; Tsai et al., 2019). Nevertheless, incorporating technological elements into metacognition can improve students' performance and reasoning capacity (Tsai et al., 2019); even games and modified games in a guided group environment promote oral communication and metacognition (Fishovitz et al., 2020).

Future research should focus on changes in teaching practice prioritizing self-regulation, implementing detailed tasks that cover a range of metacognitive strategies in different subjects, and investigating the effectiveness of applications for research such as experimentation.

Perspective 3

Figure 7. Perspective 3.

Self-regulation skills	

Source: Own elaboration.

Metacognition and self-regulation are closely linked, involving students actively participating in their learning. Research has emphasized the importance of these skills in fostering positive learning outcomes. Zimmerman (2000) stresses the role of self-regulation in effective learning and identifies self-efficacy, control of learning, task value orientation, and self-monitoring as essential components. According to Panadero et al. (2017), motivational beliefs and metacognition influence learning outcomes, so making students aware of their achievements as the result of their effort demonstrates the value of learning strategies. However, while research on these topics is well-established, results vary due to differing methodologies (Dinsmore, 2017). Consequently, there are differences in the proposed factors

that create a self-regulated learner, although studies generally show correlations between motivation and metacognition variables (McDowell, 2019).

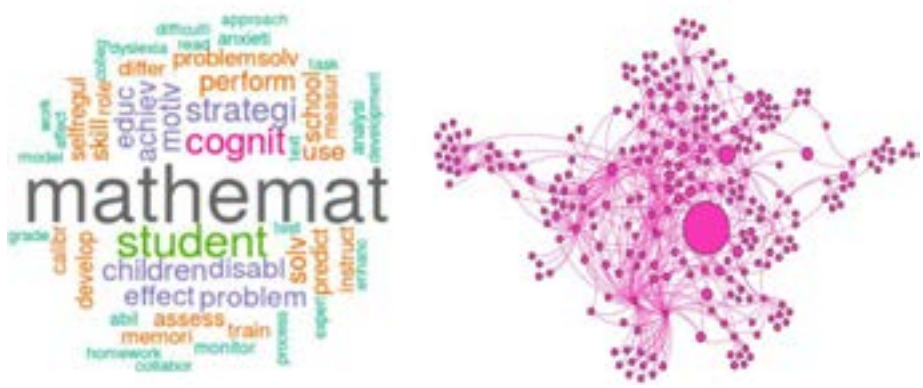
ICT (Information and Communication Technologies) in the classroom can create powerful learning environments. However, the educational community must reflect critically on structuring learning to enhance metacognitive and self-regulatory capacities (van Aalderen-Smeets & Walma van der Molen, 2015).

Cadamuro et al. (2019) suggest that for students to use ICT and promote self-regulation effectively, they should approach these tools in a metacognitive way. Additionally, Oh (2019) found that simulation-based learning using real-world cases can improve metacognition by allowing students to recognize and control their learning process. Valencia-Vallejo et al. (2019) advocate using metacognitive scaffolding in online learning environments to self-regulate learning and improve academic performance while considering the different cognitive styles of students.

There is a need for further research to investigate the effective ways of teaching self-regulated skills in undergraduate physical science classrooms. Additionally, future practice should aim to better apply research findings to the classroom context and establish a stronger connection between theory and practice.

Perspective 4

Figure 8. Perspective 4.

Metacognition in mathematics performance	

Source: Own elaboration.

Monitoring and evaluating learning processes in mathematics, including setting goals and assessing one's abilities, are essential to achieve the learning objectives, where metacognition plays a crucial role (Schneider & Artelt, 2010; Wang et al., 2016). There is substantial evidence documenting the crucial role of metacognition as a predictor of mathematical learning and problem-solving (Kuzle, 2018). Current research indicates that collaborative talk during group mathematical problem-solving is associated with improved learning outcomes (Smith & Mancy, 2018), and integrating Bloom's Revised Taxonomy and the Efklides metacognition framework can lead to designing questions that address cognitive processes and types of knowledge in mathematics education (Radmehr & Drake, 2018).

Despite the research highlighting the importance of metacognitive monitoring in mathematics teaching, there is insufficient empirical evidence on methodological aspects (Lingel et al., 2019). Desoete et al. (2019) conducted a study to address the limited empirical research on the methodological issues

related to metacognitive monitoring in mathematics education. The study analyzed the link between postdiction metacognitive skills, intrinsic motivation, prior mathematics competence, and mathematical accuracy and speed in a population of elementary school children. Their findings suggest a positive relationship between children's metacognitive postdiction skills and mathematical accuracy and speed. Similarly, Bellon et al. (2019) suggested that understanding individual differences in arithmetic requires identifying cognitive factors, including updating and metacognitive monitoring, and noticing one's errors. Zhang et al. (2020) hypothesized that students' metacognition of mathematics learning, primarily focusing on the entire learning process, plays a significant role in private tutoring decision-making across periods of high school education.

Some areas require further exploration regarding the use of metacognition to improve student performance in various domains, such as knowing the impact of intelligence types, self-concept, and motivational elements, among other factors. In addition, there is still a need to understand better how metacognition influences how students articulate and participate in classes.

Conclusions

This literature review offers a thorough overview of the evolution and patterns of research on metacognition, underscoring its beginnings and function in education. Metacognition is a multifarious construct that comprises a range of abilities, including self-awareness, self-regulation, and classroom implementation. Research shows that metacognition is pivotal in enhancing learning outcomes and can be taught and enhanced through various instructional strategies. The study underscores the importance of additional research to enrich our comprehension of the diverse components of metacognition, its correlation with cognition, and the circumstances for cultivating and instructing metacognitive skills. By addressing these areas, upcoming research can advance our knowledge of metacognition and its pragmatic implementation in various educational contexts.

The close relationship between self-regulated learning and metacognition is emphasized within the educational context. Self-regulated learning requires students to actively participate in their learning process, including setting goals, planning, monitoring, and evaluating their progress. This essentially involves the development of metacognitive skills. The literature has shown that learning outcomes are directly impacted by these two components and cognitive, metacognitive, and motivational processes. However, further understanding the theoretical relationship between metacognition and self-regulated learning and developing more effective methods to foster and enhance these skills in students is vital.

However, for these strategies to be effective, paying more attention to evaluating metacognition is necessary. Evaluating metacognition is a fundamental challenge as it is a complex construct that involves a range of skills, such as awareness, self-regulation, and classroom application. Additionally, it is necessary to consider that the definition of metacognition may vary among studies and disciplines, making evaluation difficult.

This research identified four perspectives of research: children's metacognition assessment, metacognition in students' education, self-regulation skills, and metacognition on mathematics performance. Therefore, vast possibilities of theoretical and empirical research on metacognition are opened, ranging from non-verbal metacognition measurement to strengthening the use of metacognition in different levels of education and school disciplines.

The article places the United States as the country with the most significant scientific production on metacognition. It also shows the little participation of developing countries in the research of these lines of work. This situation deserves more in-depth study since metacognition will play a crucial role in these regions.

Finally, some of the limitations found in this research are, firstly, the databases used for the initial search and the bibliometric techniques employed. Secondly, the initial search criteria contemplated a time frame of only 13 years. Finally, the natural bias of the researchers and their interpretation are limitations that arise from the design of this research.

Future lines of research

We suggest delving deeper into interindividual differences in metacognitive abilities and analyzing the type of experience or training that would enhance metacognitive sensitivity in adulthood. Relevant changes in teaching practices and teacher training are advisable to prioritize self-regulation with detailed tasks covering a range of metacognitive strategies in different school subjects and better contextualization of research results to strengthen the link between theory and practice. In addition, due to the crisis unleashed by the COVID-19 pandemic, it would be valuable to conduct a study to learn how the field of metacognition could change in this new context.

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