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A bibliometric study on problem-solving in chemistry

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ABSTRACT

Bibliometrics, as a method, enables the mapping of a specific scientific theme or body of knowledge. In this study, within the scope of Chemistry Education, we aim to analyze the interrelationship between authors and their impact on scientific productions concerning the Problem-Solving methodology, using bibliometric analysis as a foundation. To this end, data were collected from the Web of Science platform and analyzed using the VOSviewer software, based on indicators such as publication distribution, citations, co-occurrence, and bibliographic coupling. The results revealed an increase in publications on the topic from 2010 onwards, with a shift in science learning from an individual perspective to a collective approach focused on citizenship. The predominance of citations from American works is associated with the STEM movement, which boosted the promotion of science. This indicates a curricular trend toward investigative education at different educational levels, including in Brazil. Therefore, it highlights the need for strategies and methodologies that address problems in the classroom, aiming to develop skills such as decision-making, aligning with a pedagogical trend in Chemistry teaching.

PALAVRAS-CHAVE: Bibliometrics; Teaching; PBL; Chemistry; Web of Science.

Um estudo bibliométrico sobre a resolução de problemas em química

RESUMO

A bibliometria, como método, possibilita o mapeamento de um tema/conhecimento científico específico. Neste estudo, no âmbito da Educação Química, objetiva-se analisar a inter-relação entre autores e seus impactos nas produções científicas acerca da metodologia de Resolução de Problemas, utilizando a análise bibliométrica como suporte. Para isso, empregou-se a plataforma Web of Science para coleta de dados e o software VOSviewer para análise, com base em indicadores como distribuição de publicações, citações, coocorrência e acoplamento bibliográfico. Os resultados evidenciaram um aumento nas publicações sobre o tema a partir de 2010, com uma transição da aprendizagem em ciências de uma perspectiva individual para uma abordagem coletiva, focada no exercício da cidadania. A predominância de citações de trabalhos norte-americanos está associada ao movimento STEM, que impulsionou a promoção da Ciência. Observa-se, assim, uma tendência curricular em direção a uma educação com enfoque investigativo em diferentes níveis de ensino, incluindo o Brasil. Destaca-se, portanto, a necessidade de estratégias e metodologias que abordem problemas em sala de aula, a fim de desenvolver habilidades como a "tomada de decisão", alinhando-se a uma tendência pedagógica no ensino de Química.

KEYWORDS: Bibliometria; Ensino; ABP; Química; Web of Science.

INTRODUCTION

Publication in journals is the most commonly used form of communication among researchers to disseminate the results of their studies, produced in research centers and universities. In addition to this, there is a growing concern within the academic community to trace the "intellectual structure" of such productions across various fields, resulting in qualitative bibliographic investigations, such as state-of-the-art studies and literature reviews, and quantitative analyses, such as bibliometrics and scientometrics (Ferreira, 2002; Melo Ribeiro, 2017). In this context, this type of research is fundamental for mapping the historical development and evolution of a given topic and/or body of scientific knowledge, as it enables the identification of future research perspectives regarding the object of study.

Bibliometrics, scientometrics, and informetrics comprise a group of quantitative evaluation techniques (Vanti, 2002). Chosen for this study, bibliometrics serves as a "measuring tool" to analyze academic publications by using quantitative data and statistical treatments as indicators to examine the characteristics of production in a given field and its degree of dissemination (Melo Ribeiro, 2017). Bibliometrics examines relationships among different variables that present various distribution regularities, such as the number of articles that generate n citations, the number of institutions producing n doctoral theses annually, or the number of authors with n articles. Thus, bibliometric indices make it possible to assess the productivity and quality of a researcher's work, through metrics based on the number of publications and citations (Vanti, 2002).

This type of research proves effective as a methodology, given its well-defined criteria and methodological procedures, and allows for the exploration of various topics within both national and international academic contexts (Melo Ribeiro, 2017; Santos *et al*., 2022), identifying indicators and gaps to be explored. Regarding Science Education, Razera (2016) argues that, although the field is well-established with increasing scientific output across diverse areas of study over the past 50 years, there are still gaps to be addressed, particularly in aspects that have not yet been explored from a metric perspective. In other words, there remains a lack of studies involving scientometric and bibliometric analyses.

The author himself, in collaboration, conducted a study in 2019 aiming to map a metric profile of teacher education in Science Education, based on articles from five recognized journals in the field (Razera *et al*., 2019). The results, based on content, authorship, institutional affiliation, and references, were significant as they highlighted the relevance and expressiveness of the topic while revealing a lack of theoretical production and epistemic autonomy, with heavy reliance on frameworks from other fields such as Education, Philosophy, and Psychology. These findings can help guide new directions for research production on the subject.

Some recent studies in the field of Chemistry Education have employed bibliometric analysis using relevant themes as research objects. Joaquim and collaborators (2020), for example, sought to map the technique of mind maps on the Web of Science (WoS) platform between 2017 and 2020; the authors highlighted the variety of indices and correlations possible when using the platform. Chaves and Aguiar (2022) focused on the theme of "gender diversity" in chemistry education, also using WoS as the search platform. Their results emphasized the low number of publications on the topic in journals and that the international WoS platform does not reflect the actual volume of Brazilian research on the subject.

Problem - Solving (PS) stands out as one of the current methodological approaches in Chemistry Education. From this perspective, and in light of the importance of investigating the PS methodology, an approach supported by Eylon and Linn (1998), who consider it one of the main research perspectives in Chemistry Education (Tsaparlis, 2021), we pose the following question: What is the current panorama of scientific publications on PS methodology in Chemistry Education, based on a bibliometric analysis, and what gaps and future trends can be identified? In this regard, this study seeks to analyze authorial interrelations and their impacts on scientific publications concerning the PS methodology, using bibliometric analysis as a foundation.

THEORETICAL FRAMEWORK

Problem-Solving (PS) encompasses a complex sequence of activities, processes, and behaviors, for which various models have been developed and used over the years. Stamovlasis and Vaipolou (2021) define PS as a cognitive process triggered by a challenging situation in which the human mind seeks an answer to a problem encountered either in everyday experiences or during scientific work. Thus, a problem is understood as "a new or different situation from what has already been learned, which requires the search for strategies or knowledge or techniques, or both, to find a solution" (Batinga & Teixeira, 2014, p. 25). Problems are characterized by a broad range of possibilities and allow for different solution paths, demanding greater engagement, argumentation, and diverse strategies from individuals, as well as interaction with empirical and scientific knowledge. Silva and Batinga (2022) summarize that a good problem stimulates creativity, provokes reasoning, and is solvable.

Cooper *et al.* (2008) argue that improving students' Problem Solving (PS) skills is a major goal for most chemistry teachers. Additionally, Graulich (2015), when discussing PS, also highlights the teacher's role in assessing and incorporating distinct problem-solving strategies, depending on the level of education. Specifically, PS is a process through which students discover combinations of prior knowledge that they can apply to solve a new situation (namely, the problem). In this regard, it is necessary to discuss not only how students solve problems, but also the teaching and learning processes involved, as well as how problems are selected or constructed by teachers.

From a practical standpoint—solving problems—Polya (1978) argues that teachers should put themselves in the students' place, recognize their prior knowledge, try to understand their thought processes, and ask a question or suggest a step that the student might have taken. Thus, it is the teacher's role to diagnose skills, context, and conceptual level in order to construct a coherent problem that enables an appropriate solution. Regarding the problem-solving process itself, Polya (1978) proposed a four-step model: understanding the problem; devising a solution strategy; executing the strategy; and reviewing the solution (Polya, 1978; Gazonni & Ost, 2009).

Reif (1981, 1983) further suggested that, for someone to effectively solve problems, they must have: (a) a strategy for solving problems; (b) the appropriate knowledge base; and (c) a well-organized structure of that knowledge (Tsaparlis, 2021). In this context, Zoller (1993) identifies PS, along with critical thinking and decision-making, as high-order cognitive skills, considering them to be among the most important outcomes of effective learning.

Concerning the selection and/or design of problems, Assai and Bedin (2024) emphasize that a problem designed to activate high-order cognitive skills should include characteristics such as: encouraging prompts that support scientific inquiry without being overly long or exhausting; incorporating socio-scientific contexts and topics relevant to students' realities; reviewing and validating the problem variables to allow for adjustments before implementation; motivating students to seek multiple pathways to solutions; and creating open-ended problems that allow for a variety of strategies and solution routes.

METHODOLOGICAL APPROACH

According to Soares, Picolli, and Casagrande (2018), bibliometric studies are developed based on information obtained from large databases, such as *Web of Science* and *Scopus*. Therefore, this study is characterized as bibliometric research, and the data were drawn from works selected on the *Web of Science* platform. The access to the *Web of Science* (WoS) was obtained through the CAPES journal portal (Coordination for the Improvement of Higher Education Personnel – CAPES), via the CAFe access system (Federated Academic Community – CAFe). CAFe allows users to access journals and materials subscribed to by CAPES using institutional login credentials.

Given the topic under study, Problem-Solving (PS) methodology, the keywords “problem solving” and “chemistry education” were used simultaneously. The use of logical connectors “and” and “or” was necessary to narrow the search results to areas of interest—in this case, Chemistry Education. The search was conducted by topic (title, abstract, and keywords), resulting in 844 works, which were exported as a text file (.txt) and subsequently analyzed. It is important to note that no temporal filter was applied.

Data analysis was conducted using the software VOSviewer. As a bibliometric tool, the software builds connection networks based on relevant indicators of scientific production. The indicators that can be explored using VOSviewer are listed in Table 1. With the exception of “co-citation” and “co-authorship,” all other indicators formed the basis of the bibliometric analyses.

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Table 1

Types of bibliometric networks generated by VOSviewer

Type of analysis	Unit of Analysis	Description of the Relationship
Publication Distribution	Documents	The relationship among items is based on the number of documents produced over a given period.
Co-occurrence	All keywords	The relationship among items is determined based on the number of documents in wich the Keywords appear together.
Citation	Documents, sources, authors, institutions, or countries	The relationship among items is determined based on the number of times they are cited in the documents.
Bibliographic Coupling	Documents, sources, authors, institutions, or countries	The relationship among items is determined based on the number of shared references in the documents.
Coo-citation	Cited references, cited sources, cited authors	The relationship among items is determined based on the number of times are cited together in the documents.
Co-authorship	Authors, universities and countries	The relationship among items is determined basedon the co-authorship of documents.

Source: Lima (2017); Chaves and Aguiar (2022).

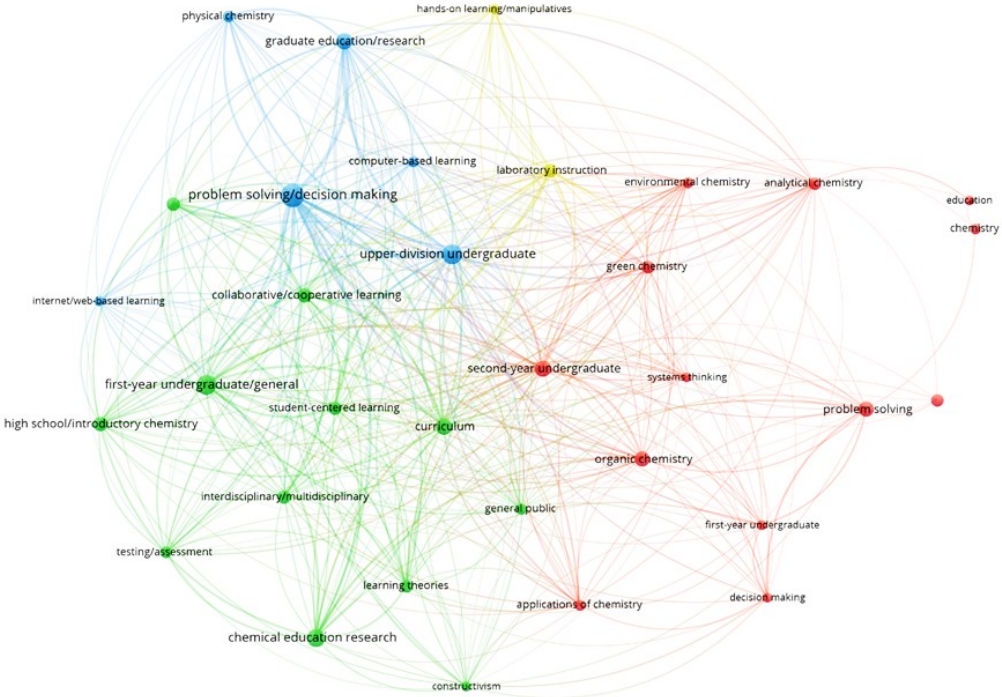
The **publication distribution** indicator establishes a relationship between the number of publications over time, allowing for the analysis of the growth trend of the subject under study. The **co-occurrence** indicator reflects the relationship between the keywords used in the publications, suggesting that keywords appearing in multiple documents are conceptually related. The **citation** indicator implies that referencing a previous work demonstrates the conceptual compatibility between both studies. Similarly, the **co-citation** indicator assumes that when two or more works are cited within the same document, there is a stronger relationship between their content. The **bibliographic coupling** indicator refers to the frequency with which documents and/or authors are cited within the same publication, indicating that the more they are cited, the greater their influence on the field of study. Finally, the **co-authorship** indicator maps relationships among co-authors of the documents. Identifying co-authorships enables the visualization of partnerships between researchers and/or research groups, helping to locate the networks involved in investigating the topic of interest

RESULTS E DISCUSSION

The **co-occurrence** indicator enabled the identification of relationships among keywords within the publications, revealing information about the research trends related to the topic under study. Among the 844 papers analyzed, a total of 1,562 author-defined keywords were found. Applying a minimum threshold of 20 occurrences as a filter, that is, selecting only the keywords that appeared in at least 20 papers resulted in a set of 33 keywords, which are represented in Figure 1.

Figure 1

Keyword Co-occurrence Map



Source: Research data from software Vosviewer (2023).

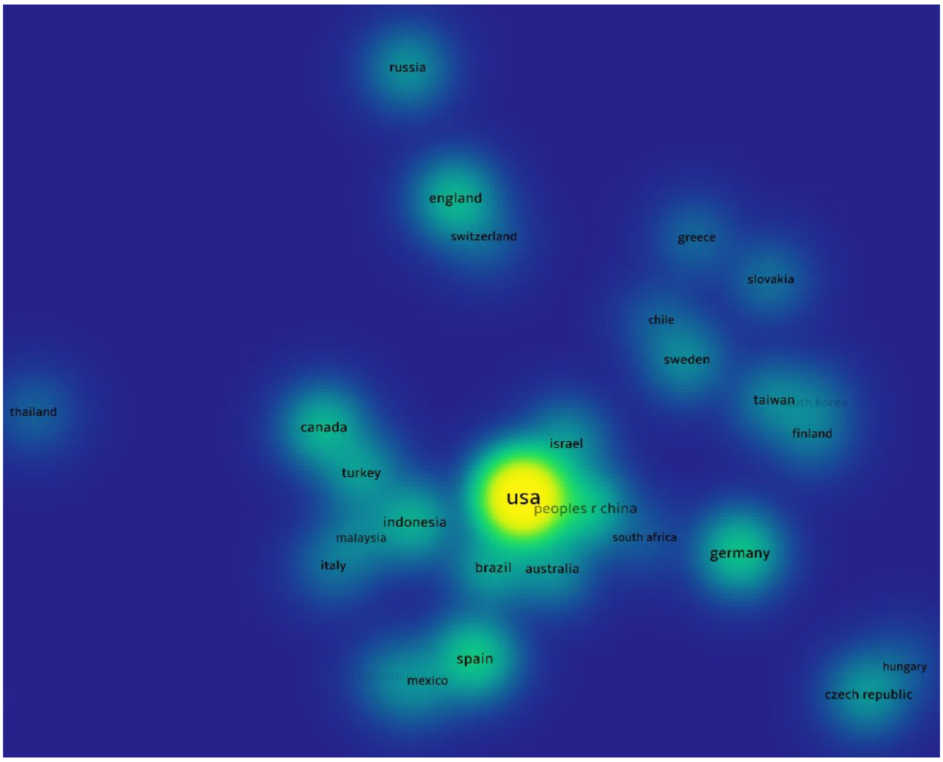
To interpret Figure 1, it is possible to observe different colors, which organize the clusters according to their similarities. Thus, keywords with the same color share connections with each other, and those with a higher number of citations appear in a larger font size.

The most frequently occurring keywords were: *problem solving/decision making (186), upper-division undergraduate* (121), *first-year undergraduate* (114), *chemical education research* (92), and *curriculum* (77), respectively. It can be inferred that Problem Solving (PS), as a teaching methodology, is a recurring theme in Chemistry Education research, emerging as a curricular trend, as indicated by the presence of the term curriculum. Furthermore, the frequent use of the terms *upper-division undergraduate* and *first-year undergraduate* supports this hypothesis, highlighting research that addresses the commitment to undergraduate/initial training of future chemistry professionals who will work in the classroom (Fernandes & Campos, 2017). In this context, Problem Solving, as a methodology to be implemented in basic education classrooms, is intrinsically linked to the need to address and discuss the methodology in teacher education programs and/or continuing education. Without providing teachers with the necessary tools, it is not possible to expect or ensure that methodologies and strategies will be effectively implemented in schools.

The analysis of author **citation frequency** by country yielded a total of 70 countries. By selecting representative publications with a minimum of five citations, this number was reduced to 33 countries. Figure 2 presents a density map.

Figure 2

Country-wise Citation map



Source: Research data from software Vosviewer (2023).

Figure 2 shows a predominance of citations in the United States, with 338 publications totaling over 5,500 citations. This is not entirely surprising, given that the *Web of Science* is a database platform based in that country. However, conceptually, the hypothesis is that, considering the nature of the topic, namely, the discussion surrounding the PS methodology, the predominance of citations in North America is primarily grounded in the STEM movement (*Science, Technology, Engineering, and Mathematics Education),* which emerged in 1990 and gained significant prominence in the U.S. beginning in 2001.

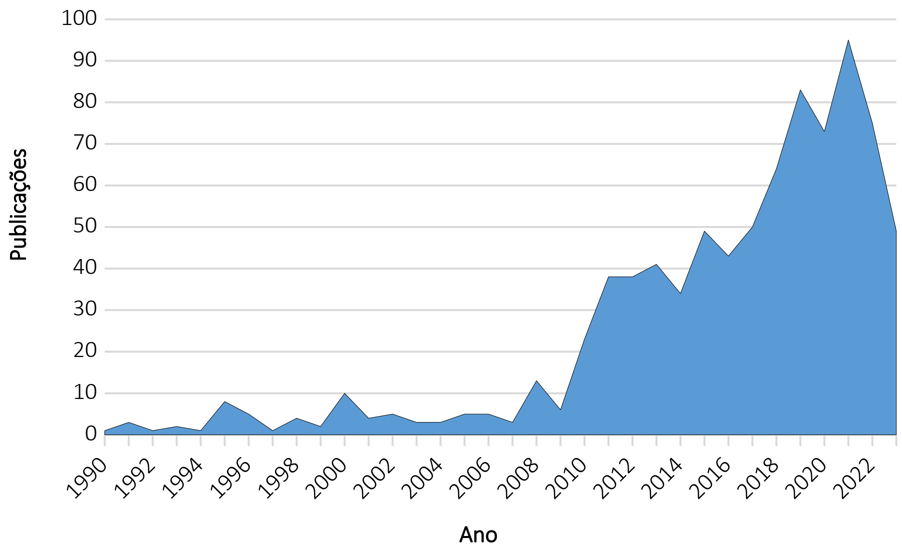
The movement proposes a teaching approach focused on the four strategic areas—Science, Technology, Engineering, and Mathematics—considered essential for sustaining and advancing the contemporary context and society (Pugliese, 2020; Melo, 2022). The premises of the STEM movement emphasize the stimulation of critical thinking not only for professional performance or work training but also for shaping individuals "as citizens capable of making ethical, sensible, collective, and transformative decisions in society" (Tolentino Neto *et al.,* 2021, p. 50), encouraging reflection in situations required on a daily basis.

This perspective aligns with the conception of PS, as this methodology involves providing students not only with procedural mastery but also with the ability to use knowledge to respond to the most diverse and complex situations (Echeverría & Pozo, 1998). In this regard, Pugliese (2020, p. 220) supports this theory by agreeing that one possible interpretation of the STEM movement is to understand it as an approach or methodology "more closely related to a way of teaching science, whose method is based on problem-solving." In this way, teaching and learning Science from the STEM perspective involves integrated, active, and student-centered learning, grounded in problems that apply scientific concepts to real-life situations.

Brazil is cited in 25 publications, with a total of 96 citations. Since the 2000s, Chemical Education in the country has guided its discussions based on an investigative approach and on citizenship education in the teaching and learning of Chemistry (Bedin, 2019), in line with national curricular guidelines (Brasil, 2000; 2006), thus aligning—albeit modestly—with this global trend. As for the **publication period**, the documents are distributed between 1991 and 2023, totaling a span of 32 years. The annual distribution of publications is shown in Graph 1.

Graph 1

Number of publications between 1990-2023



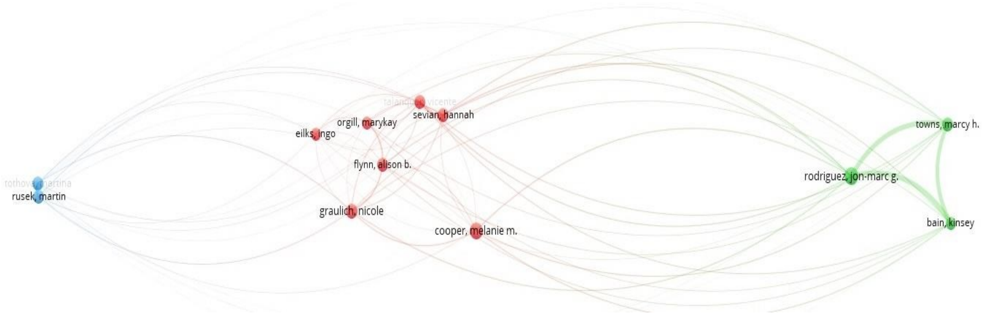
Source: Author's own work (2024).

Graph 1 shows a significant increase in publications beginning in 2010. This trend is hypothesized to reflect the expansion and influence of STEM-related approaches in other countries, which, in turn, led researchers to deepen their studies on the topic. According to Pugliese (2020), STEM is a movement that originated in the United States and spread abroad, carrying characteristic traits of the American educational system, which were incorporated into other national education systems, thereby becoming an international trend. In Brazil, the movement is still incipient, "but it is possible to observe a certain direct presence of the movement through initiatives led by non-governmental organizations focused on public schools; educational companies offering STEM activities as products; and private schools that have implemented activities in this format" (Pugliese, 2020, p. 217).

In the **bibliographic coupling** indicator, the objective was to identify authors who share citations/references. Thus, 12 authors who share citations in at least 20 documents were selected, as shown in Figure 3.

Figure 3

Bibliographic coupling map of authors



Source: research data obtainde using the Vosviewer software (2023).

This indicator assumes that the more citations a given author has, the more influential they are regarding the topic in question. Furthermore, the presence of three clusters suggests a stronger relationship in the central region of the figure, represented by the red cluster. Next is the green cluster, which, despite having fewer citations among its members, shows authorial coherence and interrelation, as indicated by the thicker connecting lines. This means there is congruence among the authors cited in the documents; therefore, it can be inferred that a common theoretical or methodological framework underpins these studies. To clarify the discussion, Table 2 presents the clusters, the selected authors, and their respective citation counts.

Table 2

Citations by authors and their related clusters

Cluster	Autor	Citações
🔴	Cooper, Melanie M.	400
🔴	Talanquer, Vicente.	224
🔴	Orgill, Marykay.	272
🔴	Flynn, Alison B.	212
🔴	Graulich, Nicole.	135
🟢	Towns, Marcy H.	116
🟢	Rodriguez, Jon-Marc G.	114
🟢	Bain, Kinsey.	103
🔴	Eilks, Ingo.	76
🔴	Sevian, Hannah.	33
🔵	Rusek, Martin.	23
🔵	Tothova, Martina.	23

Source: Author’s own work (2024).

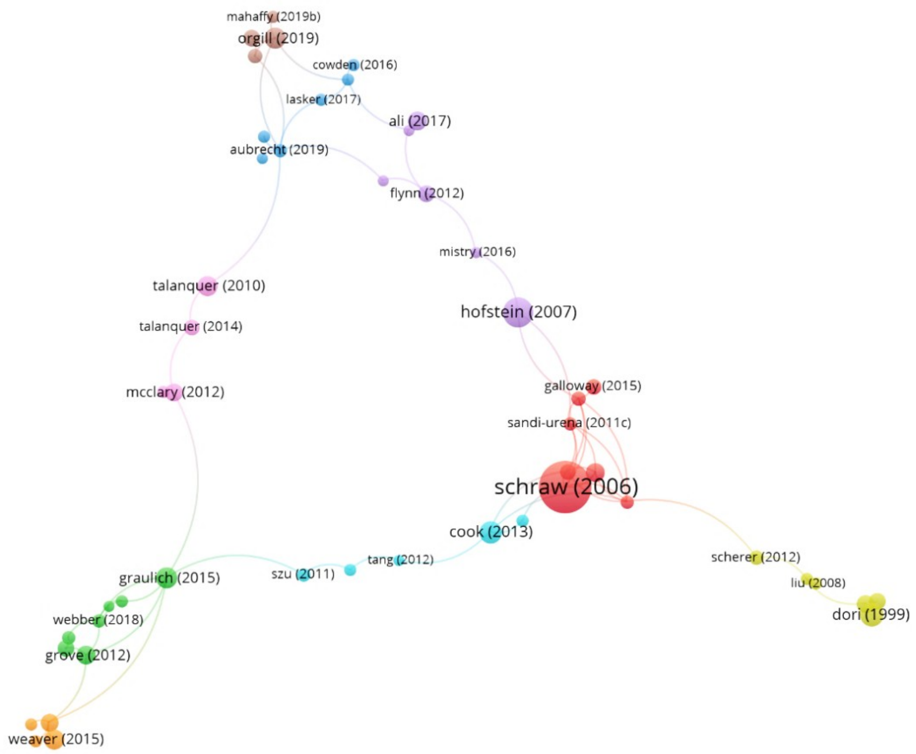
Melanie M. Cooper emerges as the most cited researcher, focusing on the discussion of problem-solving (PS) skills related to metacognition. As an example, Cooper and collaborators (2008) argue that although there is a substantial body of research on PS, assessing meaningful problem-solving is very challenging, especially in large-enrollment courses where individual interactions are not feasible.

Therefore, the authors employed a set of software tools for group PS and evaluated students' problem-solving strategies and skills as they evolved over time. Cooper and Sandi-Urena (2009) reported the development and validation of an instrument designed to assess students' metacognitive ability in chemistry PS, called the Metacognitive Activities Inventory. The authors advocate for the influence of metacognition on learning and problem-solving, as fostering metacognitive activity can lead to substantial improvements in problem-solving and, consequently, in learning chemistry.

It is clear that this cluster (red) comprises the five most cited authors in the analyzed documents. It can thus be inferred that there is a specific group of researchers who collaborate with one another in the discussion on PS. This statement can even be supported by the **citation** indicator. In other words, regarding the **citation** per document indicator, the search for documents with more than 30 citations resulted in 88 papers, 49 of which are interconnected. Figure 4 illustrates the selected documents.

Figure 4

Citation map by document



Source: research data obtained using the Vosviewer software (2023).

The most cited document is by Schraw (2006), with 598 citations. It presents a review of research on self-regulated learning and discusses the implications of this research for chemistry teaching. The author focuses on three components of self-regulated learning: cognition, metacognition, and motivation, linking these aspects of self-regulation with current practices in chemistry education. In a subsequent section, the author introduces six teaching strategies to enhance self-regulation in science classrooms, among them problem-solving (PS) strategies. It is worth noting that this author (Schraw) also addresses metacognitive aspects of learning, as does Sandi-Urena (2011), which justifies the connection between the articles shown in Figure 4. Sandi-Urena, in turn, collaborates with the most cited author, Cooper (see Table 2).

It is evident that Figure 4 includes publications by four of the five most cited authors from Figure 3: Talanquer (2010, 2014), Orgill (2019), Graulich (2015), and Flynn (2012). The convergence of data demonstrates the relevance of these authors to the topic of PS.

Flynn and Biggs (2012) present the experience of transforming a fourth-year synthetic, organic, and medicinal chemistry laboratory course at the University of Ottawa from a traditional laboratory format into a Problem-Based Learning (PBL) format. Authentic problems were developed to closely resemble the types of challenges scientists regularly face. The authors argue that the use of such problems supported the learning of concepts addressed in the course. Thus, the article's high citation count underscores the importance of employing PS in experimental classes.

Graulich (2015) – with 99 citations – discusses PS in organic chemistry. The author argues that problems in organic chemistry are often classified by content —mainly as mathematical, non-mathematical, and mechanistic. However, solving organic chemistry problems more frequently depends on trends in reactivity rather than mathematics, creating mechanisms to predict changes or rationalize spatial relationships. Therefore, solving spectral data and proposing mechanisms or step-by-step synthesis (mechanistic problem-solving) are more commonly used in organic chemistry than in general chemistry, representing a new way of thinking for students in organic chemistry classes.

The author further emphasizes that students heavily rely on rote memorization, and that traditional organic chemistry exercises, which limit themselves to stating the product, are often solved without deeper understanding (Graulich, 2015). According to the author, current practices are reduced to “problems” that students solve systematically, and that “students do what we want them to do.” In other words, a “recipe-like” approach, with predetermined and systematized outcomes, leaving no room for reflection or exploration of alternative solutions and paths. This becomes problematic, as alternative conceptions, gaps in fundamental chemical concepts, or flawed reasoning strategies seem to be hidden beneath an apparently correct answer.

Thus, an appropriate combination of instructional and assessment strategies is needed to shift students’ perceptions and promote long-term learning. Future research should therefore aim not only to establish instructional strategies that foster successful reasoning approaches beyond mechanistic issues, but also to evaluate which types of tasks are useful to enhance mechanistic problem-solving and foster other kinds of skills (Graulich, 2015).

Talanquer's works from 2010 and 2014 have 94 and 55 citations, respectively. In his 2010 publication, Talanquer discusses the importance of a chemistry curriculum focused on how chemists "think," and how forms of chemical reasoning can be used to solve meaningful and realistic problems in various domains. For the author, making judgments and decisions are critical aspects of chemical thinking, and the role of chemistry education in schools is to develop students' abilities to make informed decisions on relevant political, economic, environmental, and social issues (Talanquer, 2010; 2014).

In his 2014 study, Talanquer expands on this idea by listing cognitive processes that underpin students' critical decision-making. The author presents ten key cognitive processes that can result in a system of judgment biases, categorized into three aspects (core associative processes, inductive reasoning, and affective judgment). Thus, i) associative activation, ii) fluency, iii) attribute substitution (core associative processes); iv) reason-based decision-making, v) surface similarity, vi) recognition, vii) generalization, viii) rigidity (inductive reasoning); and ix) overconfidence, x) affect (affective judgments). This highlights the potential and contributions of PS approaches, considering the plurality of actions and cognitive processes that can be developed. It is thus important for teachers and researchers to be aware of these cognitive processes so they can design activities and problems with emphasis on specific features.

The curricular reform concerns expressed in Talanquer's research reinforce the emergence of the keyword "curriculum" and other terms related to different educational levels, corroborating the co-occurrence analysis of keywords presented in Figure 1. The ideas of Orgill (2019) – with 102 citations – align with Talanquer's views, as she argues that chemistry education often relies on reductionist thinking systems, and that it is necessary to move forward toward preparing students for active and democratic participation in political decisions based on scientific knowledge.

It is understood that the research on PS in the analyzed database primarily seeks to discuss and clarify the importance of the cognitive processes involved in scientific problem-solving. Defining which cognitive processes are necessary in PS serves to encourage students to develop such processes in pursuit of effective problem resolution. In this context, Talanquer introduces the concept of "*Chemical Thinking*," defined in Brazil as pensamento químico, which refers to a conceptual understanding of fundamental chemistry concepts, following well-defined learning progressions and presenting students with contemporary approaches to thinking and problem-solving in chemistry through realistic decision-making activities (Talanquer & Polard, 2010; Almeida & Broietti, 2023).

Additionally, it is worth noting that the publications, except for Schraw (2006), are dated from 2010 onward, supporting the trend of expanding PS-related research since that period, as shown in Graph 1.

CONCLUSION

The use of VOSviewer software as a bibliometric tool supported the mapping of publications by providing relationships among relevant indicators for understanding the overall panorama of the topic, authorial interconnections, and their implications for the field of Problem Solving (PS). In this regard, the study enables a better understanding of the scope and international reach of publications and citations, as well as their developments.

The keyword co-occurrence indicator suggests that PS has become a curricular trend across different educational levels and reflects a commitment to the training of chemistry teachers. The citation indicator by country shows a predominance of the United States, which can be explained by the origin of the platform itself. The STEM movement has contributed to the expansion of initiatives encouraging a science/chemistry education grounded in an investigative approach and in PS. Regarding the publication year indicator, a notable increase in PS-related publications has been observed since 2010, reflecting a growing trend in chemistry education research in recent years.

The research trends emerging from this bibliographic analysis, based on the citation and bibliographic coupling indicators, suggest that until 2010, authors sought to understand how learning in science occurs from a metacognitive perspective, emphasizing the importance of self-regulation in this process. Consequently, PS has emerged as a strategy to support the development of self-regulation. Over the past fifteen years, there has been a shift from a focus on individual science learning to an approach centered on citizenship education through a collective lens. Researchers now highlight the need for strategies and methodologies that address real-world problems in the classroom to simulate and promote the development of decision-making skills, which are highly valued in current educational contexts.

As a limitation of the study, it is important to note the difficulty in accessing the full text of certain articles, as some journals do not offer open access. This limits the possibility of conducting a more in-depth qualitative analysis. Nevertheless, it is understood that the analyzed *corpus* is representative of the field and provides valuable insights to inform future actions and research on Problem Solving.

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