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Eğitimde Kavram Haritalama Çalışmalarının Bibliyometrik Analizi

Bibliometric Analysis of Concept Mapping Studies in Education

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Öz

Kavram haritalama, birçok disiplinde ve düzeyde kullanılan bir yöntemdir. Bu yöntemdeki son eğilimleri belirlemek için önemli bir yöntem olarak kabul edilmektedir. Bu nedenle, bu çalışmada, Web of Science veri tabanında 1985-2021 yılları arasında yayınlanmış kavram haritalama çalışmalarının bibliyometrik bir analizi yapılmıştır. İlgili dâhil etme kriterlerini karşılayan toplam 519 makale belirlenmiştir. İlgili analizde, kavram haritalama alanındaki en önemli yazarlar, dergiler, kurumlar ve makaleler ortaya çıkarılmıştır. Ayrıca, kavram haritalama çalışmalarındaki kurumlar ve yazarlar arasındaki işbirliği açısından kavramsal kelime ağı yapısı incelenmiştir. Yapılan analizlerde, konuyla ilgili yayınların çoğunun 2013 yılında olduğu, en önemli derginin "Journal of Research in Science Teaching" olduğu ve en önemli kurumun "National Taiwan University of Science and Technology" olduğu görülmüştür. Ayrıca, kavram haritalama alanında çok fazla ortak yazarlık olmadığı gözlemlenmiştir. Ancak, Kirscher, P., Wang, M. ve Stoyanov, S. arasında ikili bir bağlantı olduğu belirtilmiştir. Sonuçlar, kavram haritalamanın geniş bir literatür tabanına sahip olduğunu göstermiştir. Çalışma, ilgili alana büyük fayda sağlayacaktır.

Anahtar Kelimeler: bibliyometri, kavram haritalama, eğitim araştırması

Abstract

Concept mapping is a method used in many disciplines and at many levels. It is considered valuable to determine the latest trends in this method. Therefore, in this study, a bibliometric analysis of concept mapping studies published between 1985-2021 on the Web of Science database has been conducted. A total of 519 articles meeting the relevant inclusion criteria were identified. In the related analysis, the top authors, journals, institutions, and articles in the field of concept mapping were revealed. In addition, the co-word network structure in concept mapping studies was examined in terms of collaboration between institutions and authors. In the analyses performed, it was seen that most publications on the subject were from 2013, the top journal was Journal of Research in Science Teaching, and the top institution

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was the National Taiwan University of Science and Technology. Furthermore, it has been observed that there is not a great deal of co-authorship in the field of concept mapping. However, a binary connection between Kirscher, P., Wang, M., and Stoyanov, S. has been noted. The results have shown that concept mapping has a broad literature base. The study will be of tremendous benefit to the associated field.

Keywords: bibliometrics, concept mapping, educational research

Introduction

Concept mapping was first developed in the mid-1970s by Joseph Novak and Cornell University graduate students as part of a research project based on the meaningful learning theory of Ausubel (1963). In this context, concept maps (CMs) that allow concepts, relationships between concepts, and examples of concepts to be presented at page level were introduced to the literature. In light of this, CMs are expressed as two-dimensional representations of a collection of concepts (Chang & Chang, 2008). Cross-links are a component of CMs in addition to concepts and defined linkages. Independent branches of concepts are connected by cross-links (Jacobs-Lawson & Hershey, 2002). CMs essentially seek to reveal details of the conceptual connections that define a knowledge structure (Schaal et al., 2010). These tools also allow students to visually present their own knowledge on any subject or concept (Hill, 2008). Thus, CMs can be used as tools to evaluate students' conceptual understanding of certain subject areas (Beyerbach & Smith, 1990).

CMs are very important tools for visualizing conceptual information structures (Hwang et al., 2020; Novak & Gowin, 1984). With such tools, the process of creating connections between concepts becomes easy for students (Kassab & Hussain, 2010; Novak, 1993). In the creation process, students can form a systematic and holistic perspective of the bonds they have created (Jianhua, 2013) and this situation is effective in the development of students' critical thinking skills (Daley & Torre, 2010; Si et al., 2019; Yue et al., 2017). Instructional interventions using CMs show that CMs are effective in learning (Cofie et al., 2021; Nesbit & Adesope, 2006) and thus contribute to the development of problem-solving skills (Malycha & Maier, 2017). Numerous studies on the effectiveness of CMs noted that CMs raise academic achievement and favourable attitudes toward learning (Horton et al., 1993) while reducing research anxiety and increasing motivation in adults (Martin et al., 2015). In addition, CMs are powerful assessment tools that can be used by teachers (Liu et al., 2010; Llinás et al., 2020). In this respect, teachers can to detect misconceptions by using CMs (Jankowska, 2010), and by analysing gaps in learning (Mühling, 2016), they can provide feedback to students on what they know (Beyerbach, 1988).

The benefits of CMs for both students and teachers have been discussed in many fields and at many teaching levels. According to Machado and Carvalho (2020), the usage of CMs in higher education has a positive impact on success, critical thinking abilities, active learning, and cooperative learning. Hwang et al. (2021) investigated the effectiveness of the CM-based problem-solving approach with 8th-grade students in China. The results of the research conducted in an experimental context showed that the problem-based approach based on CMs improved students' learning achievements, critical thinking tendencies, and problem formulation quality. Cofie et al. (2021) used CMs to teach genetics to midwifery students. In the research that used experimental design, it was stated that the teaching strategy based on CMs was effective on students' academic achievements. Llinás et al. (2020) used CMs in physics lessons in their study with first-year engineering students. The study investigated whether CMs could be used as an assessment tool. The results of the study conducted with engineering students revealed

that CMs are a good tool both quantitatively and qualitatively. In studies emphasizing the importance of teachers in teaching CMs, the systems thinking approach (de Sousa et al., 2019) and content knowledge evaluation (Garner et al., 2020) have been addressed. In addition, CMs have been discussed in different contexts such as examining the critical thinking skills of medical students with argumentation (Si et al., 2019), increasing the reading comprehension skills of weak readers (Morfidi et al., 2018), expanding the statistical knowledge of graduate students (Kapuza, 2020), and discovering 13- to 15-year-old students' awareness of careers in science (Kotkas et al., 2021).

Therefore, CMs have found their place in many disciplines, particularly in education, and they are especially valuable tools in learning and teaching processes. Therefore, in this study, it is aimed to reveal the contributions made to the literature in the field of education with CMs. In this context, we show the following as the reasons for the study:

i. Determining trends in CMs: Bibliometric analyses can help determine trends in the field of CMs by providing information about the number and diversity of studies published during a specific period.

ii. Identifying research areas: CMs is used in many disciplines. Bibliometric analyses can identify which disciplines conduct the most research on CMs and which topics are the focus of research, providing guidance for future research.

iii. Analyzing collaboration among authors: Bibliometric analyses can determine which authors have conducted the most research on CMs and the level of collaboration between authors. These analyses can offer suggestions for how future collaborations can be developed.

iv. Analyzing journals and publishers: Bibliometric analyses can identify which journals have published the most research on CMs and which publishers are prominent in this field. These analyses provide insight into where future research can be published.

v. Evaluating research quality: Bibliometric analyses can assist in evaluating the quality of research on CMs by providing information about the impact factors, citation counts, and other parameters of the journals in which CMs research is published.

In this context, the following research questions (RQs) were addressed in the study:

RQ1. What are the distribution of the;
a. top writers,
b. publications,
c. organizations,
d. articles,
e. and countries among studies on concept mapping and the use of CMs in education?

RQ2. What kind of structure about the usage of CMs in education develops in the inter-institutional setting with the cooperation of authors and the co-word network?

Previous Analysis Studies Conducted on CMs

This study is the first bibliometric review of CMs. However, comprehensive analyses in various types have also been conducted on the CMs in the relevant literature. FirstHorton et al. (1993) conducted a meta-analysis of 19 studies to determine the effect of CMs on achievement and attitude. In this context, CMs were handled separately for

teachers and students. The results obtained showed that CMs were effective on achievement at a medium level and on attitude at a large level.

Rosas and Kane (2012) analyzed 69 quantitative studies that utilized CMs. For each study, variations and distributions were taken into account, and CMs were evaluated in terms of quality. Valid, reliable, and high-quality ways to conduct CMs were proposed in the study."Batdı (2014) compared the effectiveness of the concept mapping technique and traditional learning method in terms of student achievement, permanence of knowledge, and attitude. Forty-one studies published about CMs between 2008 and 2013 were meta-analysed. The relevant publications included in the analysis were selected only from among experimental studies with control groups. In this context, according to the studies included in the meta-analysis, academic achievement was discussed in terms of teaching level, subject area, type of publication, and duration of application.

Donnelly (2017) conducted a systematic review of doctoral theses produced between 1985 and 2014 on Trochim's concept mapping methodology. In that study, in which a total of 104 theses were examined, it was observed that studies on CMs were particularly carried out in the fields of psychology and education. Studies conducted on the effectiveness of CM use were examined in terms of sampling techniques, participant characteristics, teaching strategies, and analysis methods. These analyses revealed that the concept mapping research included seven distinct teaching methodologies, and the bulk of the studies used multidimensional scaling and hierarchical cluster analysis. It was also noted that these dissertation theses on concept mapping are heavily cited.

Through a systematic review, Hartmeyer et al. (2018) investigated the concept mapping-based formative assessment approach in primary and secondary school scientific instruction. A total of nine studies meeting the inclusion criteria were examined considering the titles, aims, designs, interventions, grades, students, subjects, teaching contexts, and results. The strategies that should be considered in order to use CMs as evaluation tools in teaching were emphasized.

The other hand, Elik and Gerçek (2019) used a document analysis method to investigate studies on the usage of CMs in the field of science education in Turkey. Within the scope of that study, 11 articles about CMs published in the TR Index between 2000 and 2018 were analysed. The articles were evaluated considering the field of the study, the year it was published, the method used, data collection tools and methods, sample size, discussion, and suggestions. As a result of the related analyses, it was seen that CMs have a positive effect on the academic success of students in general, but the opposite may also be the case, and CMs are used as teaching materials rather than evaluation tools.

Finally, an evaluation was conducted on 60 articles including CMs in higher education, conducted between 1988 and 2018 by Machado and Carvalho (2020).The roles of CMs in thinking skills, collaboration, assessment of learning, and theory-practice integration were discussed. It was also reported that CMs can be supported by technology.

All of these studies have shown that concept maps have an impact on success and attitude, especially in terms of learning quality. Therefore, concept maps can be more effective than traditional learning methods and can increase students' academic achievement. Additionally, various methods have been proposed for preparing high-quality concept maps in the results of these studies. Concept maps can also be used as an assessment tool, and when used as an assessment tool in science education, strategies that need to be considered in teaching have been emphasized. In studies conducted in the field of science education in Turkey, it has been observed that concept maps have generally

positive effects. Therefore, previous studies have focused more on the quality of concept maps. However, we do not yet have information about the general trends and publication data on CMs. Therefore, with this study, it is aimed to determine the common trends in concept mapping, to reveal the topics covered with CMs in different parts of the world, and to examine how articles and top authors in the field actually affect the concept mapping literature. With this aim, efforts have been made to provide a comprehensive bibliometric analysis based on concept mapping research and datasets to be shared, thus presenting a methodological framework based on a concept mapping review.

Bibliometric Analysis as a Method

Bibliometric analysis plays a crucial role in uncovering trends and patterns within research literature. This method involves the quantitative assessment of various aspects of published research, such as citations, co-authorship, publication frequency, and more. The importance of bibliometric analysis can be understood through the following points (Donthu et al., 2021; Ellegaard & Wallin, 2015):

Identifying Research Trends: Bibliometric analysis enables researchers to identify emerging research trends and areas of interest. By analyzing patterns in publication topics and keywords, researchers can gain insights into the evolution of specific fields and the emergence of new research directions.

Mapping Knowledge Networks

Through co-citation and co-authorship analysis, bibliometrics helps in mapping the network of collaboration and influence among researchers and institutions. This provides a visual representation of how knowledge is interconnected and disseminated within a specific research domain.

Measuring Research Impact

Citation analysis is a core component of bibliometrics. It helps assess the impact and influence of individual papers, researchers, or journals. By identifying highly cited works, researchers can recognize influential contributions to the field.

Tracking Research Evolution

Longitudinal bibliometric studies allow researchers to track the evolution of research topics and their popularity over time. This information can be used to understand the trajectory of a field, as well as the factors that contribute to its growth or decline.

Forecasting Future Developments

By analyzing historical publication patterns and identifying emerging research trends, bibliometric analysis can offer insights into potential future developments in various fields. This information can guide researchers, policymakers, and stakeholders in making proactive decisions.

In summary, bibliometric analysis serves as a powerful tool for understanding the dynamics of research literature. It aids in uncovering hidden patterns, evaluating research impact, and providing data-driven insights that are valuable for researchers, institutions, and the broader scientific community.

Method

This study applied bibliometric analysis to examine research on CMs. Visual maps, the bibliometric analysis (Zupic & Ater, 2015) exposes the relationships between any publication, author, or cited author and other publications and authors. By using

bibliometric analysis approach, it is possible to determine general trends on any topic, types of publication collaborations involving field authors, and the overall status of cited publications. The bibliometric analysis and general trends of publications can also be revealed through data analysis programs that provide different visual maps (Pham et al., 2021).

Data Collection

In the data collection phase of the study, the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) (Moher et al., 2009; Pham et al., 2021) model was used. (Fig. 1). First, titles and contents inside the Web of Science (WoS) database were searched for the search phrases "concept mapping" or "concept map." The study was conducted only through WoS. Because WoS is a reputable database that includes leading scientific journals, conferences, and other academic publications. WoS covers high-quality and reliable publications and is widely used by scientists and researchers. Therefore, the WoS database was used for bibliometric analysis. In addition, the quality of the data available in this database is high and it includes a list of reliable scientific publications. WoS database provides a large amount of data such as citation numbers, publication frequency, and other important bibliometric features.

A total of 2.141 studies were gathered in this manner. Search only comprised the years (1985–2021) and the SSCI, SCI–Expanded, and A&HCI indexes. The 1985 starting point ensures that the study covers the foundational works. By including articles up until 2021, the study can provide insights into the latest trends and applications of concept mapping in the field of education. 563 studies were found in these linked studies using the "education/educational research" filter as the study field. The remaining studies were then divided into five categories: "review" (n=16), "early access" (n=11), "editorial material" (n=9), "proceeding paper" (n=5), "correction" (n=2), and "bibliography" (n=1). This left 519 studies in total. Below is the code used for the searching of WoS contents.

TS= ("concept mapping") *OR* TOPIC: ("concept map") *OR* TOPIC: ("concept mapping") *OR* TITLE: ("concept map") Refined by: WEB OF SCIENCE CATEGORIES: (EDUCATION EDUCATIONAL RESEARCH) AND [excluding] DOCUMENT TYPES: (EARLY ACCESS OR PROCEEDINGS PAPER OR BIBLIOGRAPHY OR REVIEW OR EDITORIAL MATERIAL OR CORRECTION) Timespan: All years. Indexes: SCI-EXPANDED, SSCI, A&HCI.

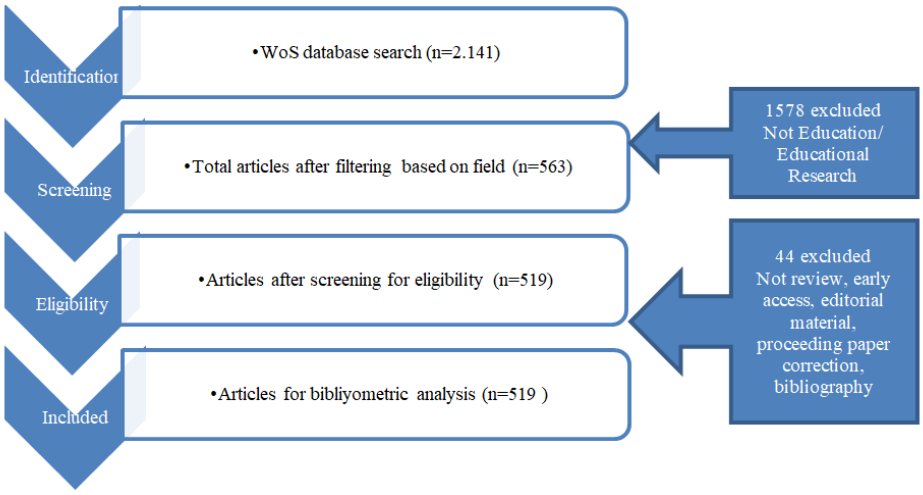


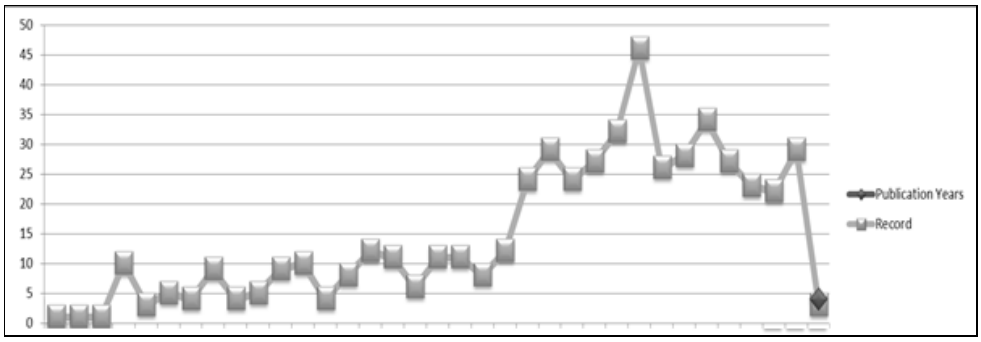
Figure 1. PRISMA diagram for CMs in the WoS database

Data Analysis

Bibliometric and descriptive analyses were used in the analysis of 519 studies obtained from the PRISMA diagram. Descriptive statistics were first performed on the data using WoS's system. The Excel program was used for this analysis. Thus, data related to CM, the distribution of studies by year, the countries with the most publications, the journals with the most publications, and the authors with the most publications were included in this analysis process.Additionally, the research's data were examined using the bibliometric analysis technique with the use of the VOSviewer tool (Van Eck & Waltman, 2017). Citation and co-citation analysis, author co-citation and keyword co-occurrence analysis, and keyword co-occurrence analysis were utilized in the bibliometric analysis of the studies on CMs (Zupic & Cater, 2015).

Figure 2. Annual CM publications between 1985 and 2021 (May)

Results



The distribution of the 519 studies obtained from online searching according to their years was examined and presented in Fig. 2. Accordingly, it can be seen that CM studies in education began in 1985. From this date onwards, it is observed that studies on CM have been carried out regularly, and the highest number (n=46) was reached in 2013. From 2013 to 2021, an average of 24 studies were conducted. This rate is approximately 6% among the 519 studies.

The 519 studies included in the analysis were authored by a total of 658 researchers. Information about the researchers in the top 10 is presented in Table 1. The highest authorship rate belongs to G.J. Hwang (%4.624, n=24).The second-largest proportion (3.083%, n=16) belongs to I.M. Kinchin. This is followed by P.A. Kirschner with 9 studies and S. Stoyanov with 8 studies. Ranking first on the list, G.J. Hwang's h-index is 14. In addition, the annual citation count is 75.42. In addition to there is a relationship between the h-index ranking and the average citations per year citation rate amount. For example, Shavelson, R.J. ranks third in the list in terms of h-index, and is also third in terms of average citations per year. Similarly, while Chiou, C.C. ranks sixth in terms of h-index ranking, he ranks seventh in terms of average citations per year.

Table 1. Top authors in CM research

Author	h-index	Sum of times cited	Citing articles	Average citations per year
Hwang, G.J.	14	905	666	75.42
Kinchin, I.M.	11	580	461	26.36
Kirschner, P.A.	5	87	82	5.12
Stoyanov, S.	6	212	208	12.47

Hay, D.B.	7	516	402	23.45
Roth, W.M.	7	402	319	13.86
Shavelson, R.J.	7	681	538	26.19
Bogner, F.X.	6	93	85	8.45
Chiou, C.C.	4	131	111	10.92
Chiu, C.H.	4	88	81	4.19

When the journal distributions of the related publications are examined (Table 2), most publications on CMs appeared in *Journal of Research in Science Teaching* (n=37). The second journal with the highest number of articles on CMs is *Computers & Education* (n=35). In this study, examining the top journals in terms of publications on concept mapping, journals with fewer than 11 articles were not included in the analysis. Accordingly, the analysed journals with the fewest articles (n=11) about concept mapping were *Research in Science Education*, *ETR&D - Educational Technology Research and Development*, *BMC Medical Education*, and *Journal of Computer Assisted Learning*.

Table 2. Top Journals

Titles	Articles	Citations	Average citations per year	Total link strength
Journal of Research in Science Teaching	37	2797	82.26	8229
Computers & Education	35	1523	72.62	7589
International Journal of Science Education	30	887	29.60	7253
Educational Technology & Society	28	462	30.80	5548
British Journal of Educational Technology	24	524	19.41	5062
Science Education	16	766	25.59	4398
Instructional Science	15	349	12.93	2795
Interactive Learning Environments	12	95	7.92	2627
BMC Medical Education	11	78	6.58	2119
ETR&D- Educational Technology Research and Development	11	192	11.29	1870
Journal of Computer Assisted Learning	11	320	15.24	2943
Research in Science Education	11	219	14.60	2670

The most cited journals for publications on CMs and their citation networks are shown in Fig. 3. While the citations of these journals vary over the years, it can be seen that *Interactive Learning Environments Journal* has been particularly prominent, especially since 2015.This journal publishes articles in the field of technology.

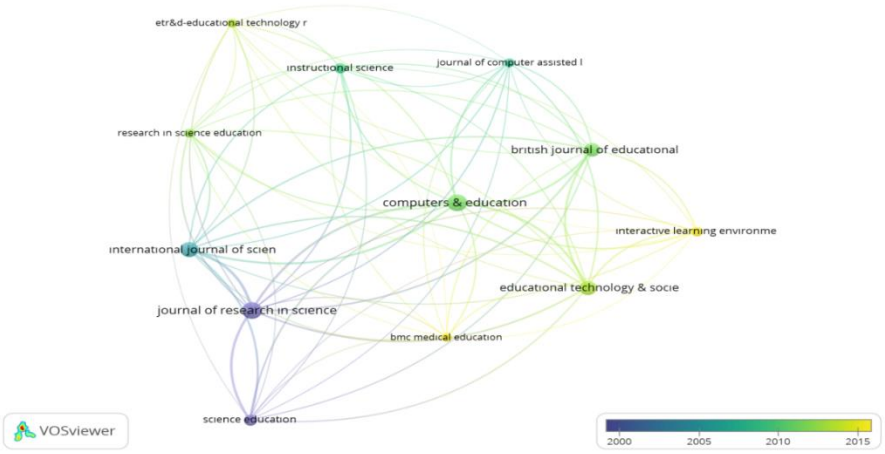


Figure 3. Top Journals That Received the Most Citations on CM in Educational Research

Table 4. Top Organizations, Geographic Areas, and Article Language

Rank	Institutions	Recorded articles	Rank	Countries / regions	Recorded articles	Rank	Language	Recorded articles
1	National Taiwan University of Science and Technology	28	1	USA	157	1	English	506
2	National Taiwan Normal University	21	2	Taiwan	154	2	Turkish	7
3	National University of Tainan	15	3	Turkey	47	3	Spanish	4
4	King's College London	13	4	England	44	4	Dutch	2
5	Universiteit Utrecht	13	5	Netherlands	43			
6	Open University of the Netherlands	12	6	Canada	30			

In Table 3, the distribution of CM studies by institutions, study languages, countries /regions is shown. In the study which reached 449 institutions in total, the biggest contribution was made by National Taiwan University of Science and Technology with 28 articles. The second institution with the highest contribution on CM is National Taiwan Normal University (n=21). It is seen that the countries that contribute the most to CM articles are the USA (n=157) and Taiwan (n=154). CM-themed articles have been published in 4 languages (English, n=506; Turkish, n=7; Spanish, n=4; Dutch, n=2)..

Table 5. The Best CM Articles in Terms of Citations

Article title	Author(s)	Year of publication	Journal	Total number of citations
1. "The ICAP framework: Linking cognitive engagement to active learning outcomes"	Cihi, M.T., & Wylie, R.	2014	Educational Psychologist	429
2. "Concept mapping - A useful tool for science education"	Novak, J.D.	1990	Journal of Research in Science Teaching	383
3. "Problems and issues in the use of concept maps in science assessment"	Ruiz-Primo, M.A., & Shavelson, R.J.	1996	Journal of Research in Science Teaching	344
4. "How a qualitative approach to concept map analysis can be used to aid learning by illustrating patterns of conceptual development"	Kinchin, I.M., Hay, D.B., & Adams, A.	2000	Educational Research	268
5. "Concept map assessment of classroom learning: Reliability, validity, and logistical practicality"	McClure, J.R., Sonak, B., & Suen, H.K.	1999	Journal of Research in Science Teaching	229
6. "Collaborative learning tasks and the elaboration of conceptual knowledge"	van Boxtel, C., van der Linden, J., & Kanselaar, G.	2000	Learning and Instruction	219
7. "Fostering collaborative knowledge construction with visualization tools"	Fischer, F., Bruhn, J., Grasel, C., & Mandl, H.	2002	Learning and Instruction	201
8. "A concept map-embedded educational computer game for improving students' learning performance in natural science	Hwang, G-J., Yang, I.H., & Wang, S.Y.	2013	Computers & Education	184

courses"				
9. "Concept mapping, mind mapping and argument mapping: What are the differences and do they matter?"	Davies, M.	2011	Higher Education	183
10. "The concept map as a research and evaluation tool - further evidence of validity"	Markham, K.M., Mintzes, J.J., & Jones, M.G.	1994	Journal of Research in Science Teaching	162

Table 4 lists the articles about CMs that have received the most citations in the field of educational research. Accordingly, the publication that received the most citations is titled "The ICAP framework: Linking cognitive engagement to active learning outcomes" published in the journal Educational Psychologist by Chi, M.T. and Wylie, R. in 2014. This article has been cited 429 times. Following this article is "Concept mapping - A useful tool for science education," published by Novak, J.D. in the Journal of Research in Science Teaching in 1990, which has a total of 383 citations. Generally, it is seen that science education and computer education studies are prominent in articles that receive the most citations in CM.

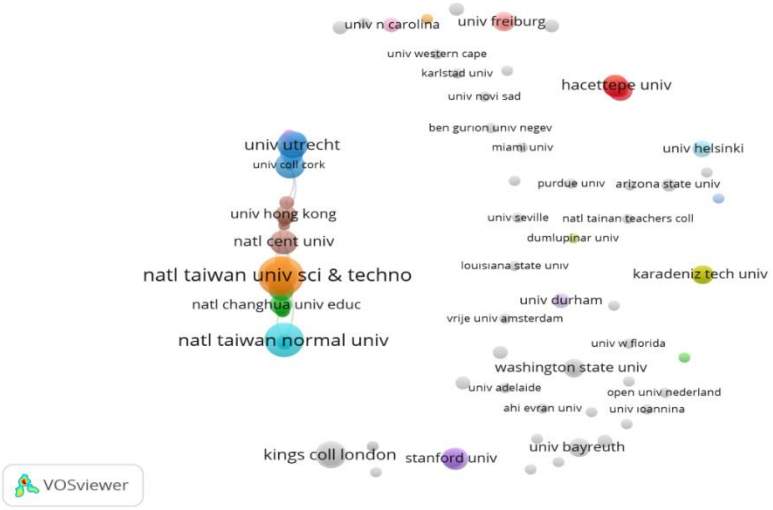


Figure 4. Institutions and Their Collaborations on CMs in Educational Research (Two or More Published Articles)

The collaboration status between institutions regarding the use of CM in education has been examined (Fig. 4). In the relevant analysis, institutions with 2 or more studies were analyzed. In this regard, a total of 58 clusters were identified. While 25 clusters had only 1 institution, 10 clusters had 2 institutions. When Fig. 4 is considered in terms of collaboration between institutions, it is seen that the best collaboration is among the universities in Taiwan. This relationship is particularly evident among National Taiwan University of Science and Technology, National Taiwan Normal University, and National Changhua University of Education.

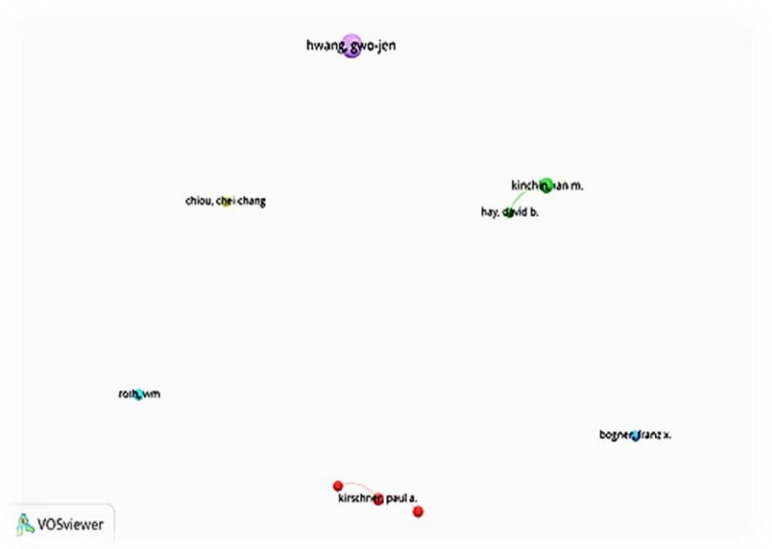


Figure 5. Network of Co-Authors in Educational Research Publishing on CMs

Fig. 5 presents the results of co-authorship analysis. According to this, it can be seen that there is not a significant amount of co-authorship in CM studies. However, there is a binary connection mainly between Kirscher, P., Wang, M., and Stoyanov, S. (document= 7). In essence, the dyadic connection between these researchers offers the potential for synergy, creativity, and a collective commitment to pushing the boundaries of concept mapping research. The other connection is between Kinchin, I.M. and Hay, D.B. (document= 10).

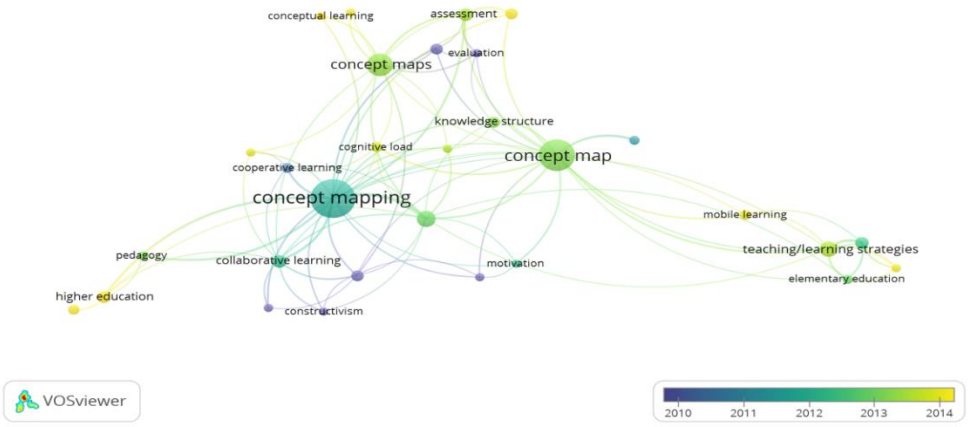


Figure 6. Co-Word Analysis for Those Appearing At Least 5 Times in the Titles and Topics

The study finally conducted a co-word analysis on the subject of CM.. The goal of the co-word analysis was to show the frequency of terms used in studies on CMs and the networks of relationships between them (Fig. 6). Accordingly, a change in the words associated with CMs was seen over the years. Between 2010 and 2012, the words "constructivism", "meaningful learning", "science", "science education", "learning", and "evaluation" were used as keywords. Between 2012 and 2013, the words "pedagogy", "motivation", "conceptual learning", and "knowledge structure" were used. Between 2013 and 2014, the words "mobile learning", "teaching/learning strategies", and "higher education" were mostly used.

Discussion and Conclusion

This study contributes to both the field of education and bibliometrics by examining the basic characteristics of the studies conducted on CM in education and providing a bibliometric evaluation of the studies carried out in this regard. A total of 519 studies from the WoS database were included in the research, and papers from the SCI-E, SSCI, and A&HCI indexes published between 1975 and 2021 were examined. It has been observed that studies on CM started in 1985 and especially since 2007, they have consistently increased. There may be several reasons for the rapid increase in research on CMs since 2007. Firstly, since that time, the processing power of computers and graphical user interfaces have significantly improved, making it more suitable for analyzing and visualizing larger and more complex datasets. Secondly, CMs have become an important tool in terms of information visualization and acquisition. Many scientists and researchers believe that this tool can help them better understand data and lead to new discoveries in the field. Thirdly, CMs have also begun to be used in education and teaching. This tool is frequently used to help students learn and better understand information. Finally, the use of CMs in scientific publications has increased. The use of CMs in articles can help authors explain complex topics in a more clear and understandable manner, thereby increasing the readability and comprehensibility of articles. The combination of these reasons may have led to the increase in research on CMs.The first study on CMs according to the relevant inclusion criteria was published by Lehman et al. (1985), in which concept mapping and Vee mapping were discussed together. However, the origin of CMs goes back much further. CMs, which were developed considering Ausubel's (1963) meaningful learning theory, were further developed by Novak and Gowin (1984) to explain how learning takes place. Afterward, CMs became widespread for the concrete visualization of what has been learned. In 2013, the number of articles on CMs reached a peak. Therefore, CMs as a component of meaningful learning have garnered a lot of attention. Although such studies decreased after those years, an average of 24 studies per year continued to be published until 2021. The interest in structuring knowledge in the brain due to continuing research on meaningful learning shows that CMs will continue intensively in the future. Because the implementation of meaningful learning means that teachers need to connect with their students, students need to explore different approaches to their learning, and students need to gain more independence in the learning process (Mayer, 2002). Therefore, we can say that both meaningful learning and CM studies will continue.

Among the researchers who contributed the most to the literature on CMs in the field of education are G.J. Hwang, I.M. Kinchin, P.A. Kirschner, and S. Stoyanov. Hwang received a total of 905 citations over time, with an annual average of 75.42 citations. When Hwang's WoS record was examined, it was determined that he was working in the field of educational technologies. When the most cited journals for publications on CMs were considered together with that information, it was concluded that CMs are better integrated with technology topics. Indeed, the most cited journals are grouped into two categories. When evaluated by years, it was seen that *Interactive Learning Environments* is the most cited journal. Machado and Carvalho's (2020) study on CM in higher education also emphasized that technology integration is intensively carried out in recent mapping studies. Similarly, the second most published journal for CM articles is *Computers & Education*. This journal also includes studies that address the combination of education and technology. Technology can further enhance the concept mapping process and provide interactive learning experiences for students. Additionally, online tools can be provided for students to create concept maps (Astriani et al., 2020). These tools allow students to visualize and organize concepts and topics in a more creative way. Furthermore, they can facilitate collaboration among students on concept maps (Islam et

al., 2020). As a result, technology can make the concept mapping process more effective and enrich students' learning experience.It has been observed that the *Journal of Research in Science Teaching* is the journal that includes the most articles on CMs.A total of 37 articles on the subject were published in this journal. Journals in which articles on CMs are published can be grouped within two clusters: science education journals and educational technology journals. Concept-based learning, conceptual change, and misconceptions are the most discussed topics, especially in science education. Therefore, the use of CMs for science education in concept teaching can be considered not only as an assessment tool but also as a teaching technique (Cofie et al., 2021; Jankowska, 2010). When studies that integrate CMs with technology are considered, it is generally observed that collaborative CMs (Liu et al., 2021; Tan et al., 2021) and performance evaluations (Hwang et al., 2020; Hwang et al., 2021; Liang et al., 2021) are included. Therefore, different fields of scientific study have been included in technology-supported CM articles (see Chen & Hwang, 2020).

This bibliometric analysis revealed that 506 CM-related articles were written in English. English journals are frequently included in the SSCI, SCI-E, and A&HCI indexes, therefore this may be related to the inclusion criteria of this study. Furthermore, the fact that the search was conducted in this language may have also influenced this result. The majority of studies were conducted in the United States, according to the distribution of the studies by countries. However, the National Taiwan University of Science and Technology produced themost of the publications. The National Taiwan Normal University and the National University of Tainan came after this school. The academic profile of the researcher who has published the most on CM belongs to Hwang, and is associated with the National Taiwan University of Science and Technology The researcher' studies in this area also demonstrate fruitful institutional collaboration. Additionally, it was found that there is close cooperation between the National Taiwan University of Science and Technology, the National Taiwan Normal University, and the National Changhua University of Education when inter-institutional connections were explored in this study. As a result of this collaboration, it can be seen that Taiwan alone has contributed to the field of concept mapping with a total of 64 articles. Therefore, institutional cooperation mostly occurs within the context of countries.

The study also includes the most cited articles on CM. Accordingly, Cihi, M.T. and Wylie, R.'s study tops the list with 429 citations. The study mentions CM for active learning purposes. The article at the top is published in a journal in a different context than the science and technology field. Its broad scope of learning may have led to many articles from different fields using it as a reference. In second place is Novak, J.D., who is the name behind the CM idea. Novak (1990) discussed CMs in science education in his article. The theoretical study has received 383 citations in all time. Although there is good institutional collaboration in CM studies, the results of co-authorship analysis show that there are not many joint authorships. In this sense, two main clusters have emerged.These clusters are Kirscher, P., Wang, M., Stoyanov, S. and Kinchin, I.M., Hay, D.B. The study also conducted co-word analysis. Accordingly, the keywords used have diversified on a yearly basis. Especially after 2014, CM studies have started to be more associated with technology and gained momentum towards mobile learning. In this context, the top study written is Liu's (2016). As in similar bibliometric studies, this study has some limitations. First of all, in this study, only certain indexes were searched via the WoS database. In addition, the search was conducted on 16 May 2021. Therefore, in this analysis, the number of studies on CMs published in 2021 appears to be only three. However, in many bibliometric studies, simultaneous searching is performed via WoS and Scopus (Archambault et al., 2009; Koumaditis & Hussain, 2017; Ospina-Mateus et al., 2019;

Sánchez et al., 2017). This allows access to different numbers of topics and publications. However, other documents such as books, or book chapters were not included in the analysis. Because these types of publications are considered insignificant in bibliometric analyses as they are cited less frequently. Additionally, books and book chapters are published over a longer period of time and reach fewer readers compared to articles published in scientific journals. Therefore, bibliometric analyses preferentially use articles published in scientific journals, conference proceedings, and other academic publications, and analyses based on these types of publications are more widely accepted (Archambault & Larivière, 2010). Even the analysis conducted only in the field of education reveals an ongoing deepening of the subject. In order to deepen the CM literature further, it is possible to separately analyse the studies on mobile learning, critical thinking, problem-based learning, and CM collaboration. In addition, researchers who will conduct bibliometric analyses in the future should understand the importance of concept mapping and be familiar with using this tool. It should not be forgotten that concept maps need to be interpreted correctly. Therefore, it may be a good idea to investigate how concept map analyses are conducted in the future.

In summary, this study has effectively illuminated the trajectory of CM research in education, its integration with technology, and the collaborative efforts that fuel its advancement. While acknowledging limitations, such as language biases and the scope of database searches, the study presents a foundation for future explorations. The ongoing deepening of the subject and the potential for further analyses in areas like mobile learning, critical thinking, and collaborative CM applications suggest a vibrant future for CM studies. As the research community moves forward, understanding the significance of concept mapping and its accurate interpretation will remain pivotal in shaping the future of educational research and practice.

References

Archambault, É., Campbell, D., Gingras, Y., & Larivière, V. (2009). Comparing Bibliometric Statistics Obtained from the Web of Science and Scopus. *Journal of the American Society for Information Science and Technology*, *60*(7), 1320-1326.

Archambault, E´., & Larivière, V. (2010). The Limits of Bibliometrics for the Analysis of the Social Sciences and Humanities Literature. *World Social Science Report* (pp. 251–254). UNESCO Publishing.

Astriani, D., Susilo, H., Suwono, H., Lukiati, B., & Purnomo, A. (2020). Mind Mapping in Learning Models: A Tool to Improve Student Metacognitive Skills. *International Journal of Emerging Technologies in Learning*, *15*(6), 4-17.

Ausubel, D. P. (1963). *The Psychology of Meaningful Verbal Learning*. Grune and Stratton.

Batdı, V. (2014). The Effect of Using the Concept-mapping Technique and Traditional Methods on the Achievement, Retention and Attitudes of Students: A Meta-analytic Study. *Dumlupınar University Journal of Social Sciences, 42,* 93-102.

Beyerbach, B. A. (1988). Developing a Technical Vocabulary on Teacher Planning: Preservice Teachers' Concept Maps. *Teaching and Teacher Education, 4*(4), 339–347.

Beyerbach, B. A., & Smith, J. M. (1990). Using a Computerized Concept Mapping Program to Assess Preservice Teachers' Thinking about Effective Teaching. *Journal of Research in Science Teaching*, *27*(10), 961-971.

Chang, S. L. & Chang, Y. (2008). Using Online Concept Mapping with Peer Learning to Enhance Concept Application. *The Quarterly Review of Distance Education, 9*(1), 17-27.

Chen, M. R. A., & Hwang, G. J. (2020). Effects of a Concept Mapping-based Flipped Learning Approach on EFL Students' English Speaking Performance, Critical Thinking Awareness and Speaking Anxiety. *British Journal of Educational Technology*, *51*(3), 817-834.

Cofie, R., Sarfo, J.O., & & Doe, P.F. (2021). Teaching and Learning of Genetics Using Concept Maps: An Experimental Study among Midwifery Students in Ghana. *European Journal of Contemporary Education, 10*(1), 29-34.

Çelik, M., & Gerçek, C. (2019, June). Evaluation of Researches Concerning Concept Maps in Science Education. In *Proceedings of the International Congresses on Education (ERPA 2019)* (pp. 184-188).

Daley, B. J., & Torre, D. M. (2010). Concept Maps in Medical Education: An Analytical Literature Review. *Medical Education, 44*(5), 440–448.

De Sousa, L. O., Hay, E. A., & Liebenberg, D. (2019). Teachers' Understanding of the Interconnectedness of Soil and Climate Change When Developing a Systems Thinking Concept Map for Teaching and Learning. *International Research in Geographical and Environmental Education*, *28*(4), 324-342.

Donnelly, J. P. (2017). A Systematic Review of Concept Mapping Dissertations. *Evaluation and Program Planning*, *60*, 186-193.

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to Conduct a Bibliometric Analysis: An Overview and Guidelines. *Journal of Business Research*, 133, 285-296.

Ellegaard, O., & Wallin, J. A. (2015). The Eibliometric Analysis of Scholarly Production: How Great is the Impact?. *Scientometrics*, 105, 1809-1831.

Garner, J. K., Kaplan, A., Hathcock, S., & Bergey, B. (2020). Concept Mapping as a Mechanism for Assessing Science Teachers' Cross-disciplinary Field-based Learning. *Journal of Science Teacher Education*, *31*(1), 8-33.

Hartmeyer, R., Stevenson, M.P., & Bentsen, P. (2018). A systematic Review of Concept Mapping-based Formative Assessment Processes in Primary and Secondary Science Education. *Assessment in Education: Principles, Policy & Practice, 25*(6), 598-619.

Hill, L. H. (2008). Concept Mapping to Encourage Meaningful Student Learning. *Adult Learning, 16*(3/4), 7-13.

Horton, P. B., McConney, A. A., Gallo, M., Woods, A. L., Senn, G. J., & Hamelin, D. (1993). An Investigation of the Effectiveness of Concept Mapping as an Instructional Tool. *Science Education, 77*(1), 95–111.

Hwang, G. J., Huang, H., Wang, R. X., & Zhu, L. L. (2021). Effects of a Concept Mapping-Based Problem-posing Approach on Students' Learning Achievements and Critical Thinking Tendency: An Application in Classical Chinese Learning Contexts. *British Journal of Educational Technology*, *52*(1), 374-493.

Hwang, G. J., Zou, D., & Lin, J. (2020). Effects of a Multi-level Concept Mapping-based Question-posing Approach on Students' Ubiquitous Learning Performance and Perceptions. *Computers & Education*, *149*, 103815.

Islam, I., Munim, K. M., Oishwee, S. J., Islam, A. N., & Islam, M. N. (2020). A Critical Review of Concepts, Benefits, and Pitfalls of Blockchain Technology Using Concept Map. *IEEE Access*, *8*, 68333-68341.

Jacobs-Lawson, J. M., & Hershey, D. A. (2002). Concept Maps as an Assessment Tool in Psychology Courses. *Teaching of Psychology, 29*(1), 25-29.

Jankowska, M. (2010). Concept mapping-a Reflective Tool in Personal Development Planning. *Assessment, Teaching & Learning Journal, 10*, 14–17.

Jianhua, L. (2013). The Assessment Agent System: Design, Development, and Evaluation. *Educational Technology Research and Development, 61*, 197-215.

Kapuza, A. (2020). How Concept Maps with and without a List of Concepts Differ: The Case of Statistics. *Education Sciences*, *10*(4), 91.

Kassab, S. E., & Hussain, S. (2010). Concept Mapping Assessment in a Problem-based Medical Curriculum. *Medical Teacher, 32*(11), 926–931.

Kotkas, T., Holbrook, J., & Rannikmäe, M. (2021). Exploring Students' Science-related Career Awareness Changes Through Concept Maps. *Education Sciences, 11*(4), 157.

Koumaditis, K., & Hussain, T. (2017). Human Computer Interaction Research Through the Lens of a Bibliometric Analysis. In *International Conference on Human-computer Interaction* (pp. 23–37). Cham: Springer.

Lehman, J.D., Carter, C., & Kahle, J.B. (1985). Concept Mapping, Vee Mapping, and Achievement - Results of a Field-study with Black High-school Students. *Journal of Research in Science Teaching, 22*(7), 663-673.

Liang, H. Y., Hsu, T. Y., & Hwang, G. J. (2021). Promoting Children's Inquiry Performances in Alternate Reality Games: A Mobile Concept Mapping-based Questioning Approach. *British Journal of Educational Technology*, 1-20.

Liu, P. L. (2016). Mobile English Vocabulary Learning Based on Concept-mapping Strategy. *Language Learning & Technology*, *20*(3), 128-141.

Liu, P. L., Chen, C. J., & Chang, Y. J. (2010). Effects of a Computer-assisted Concept Mapping Learning Strategy on EFL College Students' English Reading Comprehension. *Computers & Education, 54*(2), 436–445.

Liu, S., Kang, L., Liu, Z., Fang, J., Yang, Z., Sun, J., ... & Hu, M. (2021). Computer-supported Collaborative Concept Mapping: The Impact of Students' Perceptions of Collaboration on Their Knowledge Understanding and Behavioural Patterns. *Interactive Learning Environments*, 1-20.

Llinás, J. G., Macías, F. S., & Márquez, L. M. T. (2020). The Use of Concept Maps as an Assessment Tool in Physics Classes: Can One Use Concept Maps for Quantitative Evaluations?. *Research in Science Education*, 1789-1804.

Machado, C.T., & Carvalho, A.A. (2020). Concept Mapping: Benefits and Challenges in Higher Education. *The Journal of Continuing Higher Education, 68*(1), 38-53.

Malycha, C. P., & Maier, G. W. (2017). The Random-map Technique: Enhancing Mind-Mapping with a Conceptual Combination Technique to Foster Creative Potential. *Creativity Research Journal, 29*(2), 114–124.

Martin, L. G., Martin, F. A., & Southworth, E. (2015). A Critical Review of Concept Mapping Research Literature: Informing Teaching and Learning Practices in GED

Preparation Programs. *New Horizons in Adult Education and Human Resource Development, 27*(3), 27–45.

Mayer, R. E. (2002). Cognitive Theory and the Design of Multimedia Instruction: An Example of the Two-way Street Between Cognition and Instruction. Cambridge University Press.

Moher, D., Liberati, A., Tetzlaff, J., & Altman, D. G. (2009). Preferred Reporting Items for Systematic Reviews and Meta-analyses: The PRISMA Statement. *International Journal of Surgery, 8* (5), 336-341.

Morfidi, E., Mikropoulos, A., & Rogdaki, A. (2018). Using Concept Mapping to Improve Poor Readers' Understanding of Expository Text. *Education and Information Technologies*, *23*(1), 271-286.

Mühling, A. (2016). Aggregating Concept Map Data to Investigate the Knowledge of Beginning CS Students. *Computer Science Education, 26*(2–3), 176–191.

Nesbit, J. C., & Adesope, O.O. (2006). Learning with Concept and Knowledge Maps: A Meta-analysis. *Review of Educational Research, 76*, 413–448.

Novak, J. D. (1993). Human Constructivism: A Unification of Psychological and Epistemological Phenomena in Meaning Making. *International Journal of Personal Construct Psychology, 6*, 167–193.

Novak, J. D., & Gowin, D. B. (1984). *Learning How to Learn*. Cambridge University Press.

Ospina-Mateus, H., Jiménez, L. A. Q., Lopez-Valdes, F. J., & Salas-Navarro, K. (2019). Bibliometric Analysis in Motorcycle Accident Research: A Global Overview. *Scientometrics*, *121*(2), 793-815.

Pham, H. H., Vuong, Q. H., Luong, D. H., Nguyen, T. T., Dinh, V. H., & Ho, M. T. (2021). A Bibliometric Review of Research on International Student Mobilities in Asia with Scopus Dataset between 1984 and 2019. *Scientometrics*, *126,* 5201-5224.

Rosas, S. R., & Kane, M. (2012). Quality and Rigor of the Concept Mapping Methodology: A Pooled Study Analysis. *Evaluation and Program Planning*, *35*(2), 236-245.

Sánchez, A. D., Del Río, M. D. L. C., & García, J. Á. (2017). Bibliometric Analysis of Publications on Wine Tourism in the Databases Scopus and WoS. *European Research on Management and Business Economics*, *23*(1), 8-15.

Schaal, S., Bogner, F. X., & Girwidz, R. (2010). Concept Mapping Assessment of Media Assisted Learning in Interdisciplinary Science Education. *Research in Science Education*, *40*(3), 339-352.

Si, J., Kong, H. H., & Lee, S. H. (2019). Developing Clinical Reasoning Skills Through Argumentation with the Concept Map Method in Medical Problem-based Learning. *Interdisciplinary Journal of Problem-Based Learning*, *13*(1), 5.

Tan, E., de Weerd, J. G., & Stoyanov, S. (2021). Supporting Interdisciplinary Collaborative Concept Mapping with Individual Preparation Phase. *Educational Technology Research and Development*, *69*(2), 607-626.

Yue, M., Zhang, M., Zhang, C., & Jin, C. (2017). The Effectiveness of Concept Mapping on Development of Critical Thinking in Nursing Education: A Systematic Review and Meta-analysis. *Nurse Education Today, 52*, 87-94.

Zupic, I., & Čater, T. (2015). Bibliometric Methods in Management and Organization. *Organizational Research Methods, 18*(3), 429-472.