



Research and teaching methods for electrical circuits in science, technology, and engineering: A Bibliometric Analysis

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Abstract

This study employed a bibliometric analysis to investigate a variety of approaches and research patterns in the instruction of electric circuits within the realms of science, technology, and engineering. Through a bibliometric review, the current body of research was examined, offering quantitative insights through statistical analysis. The distribution of paper titles, author keywords, and keywords plus was analysed statistically to determine trends in research on electric circuit methodologies. Based on the Scopus database, only 94 documents covering the period 1988 to 2023 were identified, indicating a limited scope of the research. Study results identified bibliographic information, diverse methodologies, and research trends, providing future research on electric circuits with valuable quantitative insights. Compared to traditional methods of teaching electrical circuit concepts, previous research emphasized the use of hands-on, virtual applications and inquiry-based learning techniques, etc. Bibliometric analysis revealed that no studies have included or documented the table method for teaching electric circuits. It was recommended that future research evaluate the effectiveness of the table method among science teachers.

Keywords: Classroom methodologies, electric circuits, research trends.

1. Introduction

Today's science education has evolved and expanded into one of the most promising aspects of society's changes and advances, influencing very rapid changes in people's daily lives, particularly in science classrooms. To transform teaching and learning processes, pedagogy in science education research must be incorporated into teaching practices. For example, research-based pedagogy in science classrooms has led to inquiry-based learning, where students actively explore scientific concepts through hands-on experiments and investigations. As electricity has developed in our daily lives and science curriculums, it has become an increasingly important part of science and technology. The understanding of electricity has evolved over centuries of scientific inquiry and experimentation. This ongoing process of discovery and innovation continues to shape our understanding of this important

aspect. Despite being invisible, electricity plays a prevalent role in our lives. As technology progresses, there is immense potential for future advancements in electricity. Scientists are exploring new materials and technologies that could lead to more efficient and sustainable methods of electricity generation and storage. One exciting area of research is the development of wireless electricity transmission. Various models and methodologies have been employed to explain electric circuits, but none have successfully covered all aspects (Hart, 2008).

Electric circuits have played a pivotal role in scientific discoveries and technological advancements throughout history. Science, engineering, and technology all exhibit this characteristic, making it an integral part of the curriculum. Among the most important aspects of science curriculum, electric circuits require specialized instructional pedagogy to ensure effective or meaningful instruction. By incorporating pedagogy in science education research into teaching practices, educators can gain a deeper understanding of how students learn and tailor their instruction accordingly (Carrión-Martínez et al., 2020). Pedagogy in the teaching and learning play a crucial role in science education. Certain abstract concepts, pose challenges for students due to available methodologies and approaches applied to the teaching of electric circuits (Anita et al., 2018). Considering the characteristics of this study, a bibliometric review of research on methodologies, approaches, instructions, strategies, etc., related to school science instruction of electric circuits was undertaken.

In line with this study, Falloon (2019) explored the use of different approaches that have been researched and are available to engage higher-order cognitive abilities in understanding electric circuits. The research examined various models and methodologies that have been studied and utilized for school science instruction in electric circuits. Through engagement in electric circuits, these approaches aim to promote meaningful learning. In the study, it was emphasized that the teaching and learning of electrical circuits should be approached in a cognitive, flexible, and diverse manner, emphasizing the use of existing and evidence-based instructional practices that are known to be successful.

In this study, methodological research trends were explored using bibliometric analysis or reviews of the relevant published articles. This was done to identify any gaps or essential factors in teaching and learning of electric circuits. To shed light on this gap, this paper presents an analysis of the literature related to electric circuits methodologies, based on a bibliometric analysis. The study anticipated that the findings would make a valuable contribution to the research trends and researchers exploring electric circuits in science education. Using bibliometric analysis, the study was aimed at providing a comprehensive understanding of the current research landscape in electric circuits and science education. The purpose of this work was to bridge the gap between electric circuit methodologies and research trends in science education.

2. Literature review

An overview of the methodologies and trends in electrical circuit research is presented in this section. This approach enabled identification of relevant theories, methods, and gaps in existing research related to the title of this study. Using a literature review, Santos et al. (2019) conducted a study focusing on classroom innovations, technologies, experimental activities, and evaluation within the realm of Physics and Science teaching. One noteworthy aspect highlighted by Santos et al.'s research is the limited attention given to pedagogical content knowledge and research. The study aimed to gather research trends and methodological underpinnings in science education and research. Data sources included articles, books, and book chapters from various repositories and mainly Scopus. The sources

were also classified based on Physics themes (electric circuits in this paper), methodology, didactic resources, and theoretical foundation. As a result, this paper provides readers with a comprehensive overview of the possibilities for incorporating scientific methods and research into teaching electric circuits. Science instructors' favour and views the conventional approach as the most efficient means of covering extensive content within the allocated period of time. The dissemination of substantial information over a relatively short timeframe makes traditional teaching methods preferable. According to Borrego and Bernhard (2011), while these methods can easily deliver material to large student populations, evidence suggests that they may not necessarily foster high levels of learning or retention. The drawback of this approach lies in its assumption that students are passive recipients waiting for knowledge to be imparted. An effective methodology goes beyond simply posing questions or assigning activities; it must facilitate the type of critical thinking that is characteristic of disciplined knowledge and practices. Traditional method has not been proven effective in cultivating critical thinking skills essential for future professional roles in science (Pitterson & Streveler, 2015).

Kollöffel and De Jong (2013 study focused on electrical circuits, emphasizing that the curriculum typically comprises two main components: textbook-based instruction and practical. The textbooks generally adopt a factual and traditional approach, providing students with information, definitions, laws, and equations to solve standard circuit problems. These lessons emphasize procedural skill and the memorization of facts and definitions. Practical lessons, involving the building of electrical circuits and measurements, supplement textbook learning. While these hands-on experiences are crucial for skill development and gaining real-world familiarity, they also come with limitations. Students often prioritize making their circuits functional over understanding the causal relationships between variables and outcomes. Additionally, real-world scenarios introduce unexpected challenges and deviations from textbook principles, such as non-ideal equipment and varied measurement outcomes. The lack of systematic experimentation and the failure to connect hands-on activities with textbook knowledge further hinder the development of a comprehensive conceptual understanding of electric circuits among students.

A study was conducted to examine the data collected from the research (Anita et al., 2018) about the understanding of the concept of electric power and circuits among physics teacher candidates. To master concepts, one must be able to explain, interpret, analyse, and apply physical concepts to physics problems. In instances where the student could not answer electric circuit questions, it was assumed that the student was not familiar with the concept being tested. It is crucial for a student physics teacher to understand electric circuits as it forms the basis of their physics knowledge. Without a solid understanding of these concepts, they would struggle to explain and interpret various physical phenomena. They would also struggle to analyse complex circuits and apply their knowledge to solve physics problems. Mastery of electric circuits was essential for their future role as physics educators. Based on the analysis of prospective physics teacher students' understanding of electrical circuits, it was determined that the understanding ability of physics teacher students was still low and indicated a low percentage on average (Anita et al., 2018).

Al-Holou and Abdallah (1996) developed a Computer-Based Instruction (CBI) innovative method and discussed some of the difficulties and challenges associated with replacing some aspects of traditional classroom learning with it. CBI focuses on the electric circuit elements and laws in the Electro physics Curriculum. While the method has some limitations, it has also proven to be an efficient and cost-effective method for developing and delivering instructional materials. In addition, it provided a variety of customizable ways of delivering clear instructions, thereby minimizing misunderstandings and misconceptions through

Computer-Based Instruction (CBI). By providing clear instructions in customizable formats, CBI allowed students to grasp complex concepts more easily and reduces the chances of confusion or misinterpretation. This ultimately leads to improved retention and comprehension of the subject matter.

Geddis (1993) provided a depiction of the way pedagogical content knowledge contributes to the transformation of subject matter content for teaching. In the paper, a group of preservice secondary science teachers deliberated how to teach electrical current flow within a simple electric circuit as part of a methodology. They were concerned about relevant methodologies that accommodated students' misconceptions about electrical current flow. A methodology provided novice teachers with a more sophisticated understanding of their craft using ideas about transforming content for instruction, pedagogical content knowledge, and reflection that gives students a reason to do so. By critically analysing their own teaching practices and adjusting to their students' needs, reflection plays an important role in transforming subject matter content for instruction. Through reflection, teachers identify areas where their pedagogical content knowledge could be enhanced. They could also develop strategies to improve the quality of instruction and student learning outcomes.

As several studies have indicated that effective methods can enhance achievement in electric circuits learning environments, researchers propose the advantages of incorporating active learning approaches. This has led to a call for increased utilization of active learning methods in science classrooms, particularly in the instruction of abstract concepts like those found in electric circuits. This initiative has prompted research into innovative ways to genuinely involve students, with some approaches focusing on the integration of technological devices. Interactive learning tools are applied to guide students through examples within the classroom, and instructional videos are employed as pedagogical tools, requiring students to watch them before or during class to streamline the introduction of concepts or formulas. While it is recommended to design learning environments that actively engage students, teachers should be mindful of how these activities are perceived by the students. In addition to the examples provided in this paragraph, the study aimed to explore various methodologies applied to the teaching and learning of electric circuits (Pitterson & Streveler, 2015).

Bernhard and Carstensen (2002) note that students' conceptions of circuit theory and electricity are less well researched. Studies have been conducted on how students understand simple circuits, but little research has been carried out on how students understand complex circuits. Students' understanding of more advanced topics in DC-theory and AC-theory as well as the application of innovative methods to circuits remain unresearched. An investigation was conducted to investigate engineering students' understanding of electrical circuits, including periodic signals and transients. Based on the findings reported, some learning approaches developed by using conceptual labs were used to enhance students' understanding of concepts. In science education research at the time, innovative methods, such as conceptual labs, were overlooked in addressing electric circuits. Further research was recommended on students' understanding of electrical circuits and the effectiveness of different learning methods.

Research on electric circuit was conducted by O'Connell (2015) and applied Team-Based Learning (TBL) method. According to O'Connell, TBL represents a student-centered active learning approach where students independently delve into new conceptual material before classroom instruction. Subsequently, significant class time was dedicated to collaborative group work, tackling progressively challenging problems and applications based on the introduced material. TBL not only enhances students' grasp of course content compared to

traditional lecture-based methods but also fosters the development of transferable professional skills, including self-directed learning, problem-solving, and interpersonal teamwork abilities. Recognizing these potential advantages, TBL became the primary teaching and learning strategy for a two-course level electric circuit theory sequence, implemented since 2010. The paper outlined positive modifications in the TBL implementation within the circuit theory sequence, influenced in part by student evaluations of the strategy. Additionally, the instruments used for assessing student learning in TBL-taught courses were detailed, providing evaluation insights that affirm the effectiveness of the revised TBL version in facilitating both technical content and various professional skills in the electric circuit theory sequence.

One of the studies on electric methodology was outlined to introduce a flipped classroom approach for instructing an Electric Circuits course. The method stipulates that before each scheduled class session, students must view a pre-recorded concise lecture, delving into detailed topics and featuring solved problems. The recording process involved utilizing a Tablet PC in conjunction with PowerPoint, OneNote, and Camtasia as the capturing software. The study further created a series of narrated dynamically worked-out problems covering various difficulty levels, encouraging students to watch and enhance their problem-solving skills. A standard lecture format comprises a brief review of concepts, followed by the resolution of more challenging problems linked to the lecture content. Azemi (2013) extensively discussed this approach, highlighting its advantages and disadvantages. Preliminary assessments from a student group indicated positive feedback regarding the proposed approach.

In 1996, Doering introduced a paper exploring the conceptualization of electric circuits through 'Circuitviz' animations and analogies. The CD-ROM supplement accompanying this publication elaborates on the methodology. The aim was to enhance students' learning experiences by visualizing the dynamic behaviours of electric circuits. Traditionally, circuit variables such as voltage, current, power, and stored energy were displayed separately on Cartesian plots alongside circuit schematics. However, recent advancements in scientific visualization suggest that consolidating all relevant data into a single visual representation, or graphic metaphor, improves the viewer's ability to grasp global relationships and enhances overall understanding. The visual cues drew on mechanical analogies, primarily the water-flow analogy, leveraging students' existing knowledge. Initial classroom tests revealed that Circuitviz effectively motivates discussions on circuit operation by illustrating qualitative circuit behaviour. Most students reported an improvement in their understanding of transient circuit behaviour through this technique.

The study conducted by Kapartzianis and Kriek (2014) also contributed to the expanding literature exploring students' conceptual grasp of electricity through the introduction of a multidimensional and practical approach to conceptual change. Model-based activities aligned with a six-stage conceptual change model were integrated into a four-week course. The efficacy of these activities was assessed in terms of altering students' misconceptions about simple electric circuits to align with scientifically accepted ideas. Frequency analysis results for both pre- and post-tests indicated a notable reduction in the percentage of students harbouring identified misconceptions. During post pre-test interviews, most students justified their answers incorrectly, but in the post post-test interview, over 80% provided correct responses.

Reba et al. (2022) advocates the integration of innovative pedagogical approaches alongside traditional teaching methods to sustain contemporary students' attention spans. They introduced an enhanced Jigsaw learning method for teaching Circuit Analysis to first-

year students. Diverse teams were formed based on student personalities, promoting effective learning units and team coherence. Feedback analysis at the session's end revealed a noteworthy shift in students' understanding levels, with a substantial 20% improvement in assessment scores for personality types. Post-session data demonstrated increased student confidence in solving Direct Current (DC) and Alternating Current (AC) circuits. A comparative analysis between the conventional teaching method and the Jigsaw approach indicated the latter's effectiveness for both student learning and faculty teaching of electric circuits. The enhanced Jigsaw method enhances learning outcomes and added enjoyment to the learning process.

The purpose of this study was to conduct bibliometric analysis of research conducted in accordance with pedagogy and methodologies applied to the teaching and learning of electric circuits. Bibliometric analysis plays a crucial role in educational research by providing a comprehensive overview of the existing literature and identifying trends, gaps, and areas for further exploration. It helps researchers understand the current state of knowledge in a particular field, make informed decisions about research directions, and contribute to the advancement of pedagogy and methodologies in teaching electric circuits. Bibliometric analysis was conducted to achieve the objectives of the study, by reviewing existing methodologies used in classroom settings (Espera & Pitterson, 2019). Despite this, little research has been undertaken on the instructional pedagogies of teaching electric circuits in science classrooms.

Arici (2019) conducted a bibliometric review focusing on augmented reality (AR) in science education articles. The examination encompassed all articles dedicated to the utilization of "augmented reality" in science education, providing a comprehensive assessment. The variables considered in the bibliometric mapping analysis were confined to the VOSviewer analysis. This investigation aimed to identify any gaps or essential factors by scrutinizing methodological research trends and the outcomes of the bibliometric mapping analysis in all relevant published articles. Through this extensive content and bibliometric mapping analysis, it was anticipated that the findings will make a valuable contribution to researchers exploring AR in science education. The aspiration is for this work to serve as a valuable resource for researchers in this field in the future.

This paper utilized bibliometric analysis of the literature to address the research gap in the teaching and learning of electric circuits. According to Lozada et al., (2021), the goal of a bibliometric analysis is to develop quantitative research by applying statistical methods to evaluate several characteristics of specific bibliographic information. In this paper, a detailed description of the teaching methodologies and research that was conducted in the teaching and learning of electrical circuits is provided, followed by a summary of what was discovered. In the teaching of electric circuits, research findings can be utilized to inform instructional strategies and assessment practices. Additionally, the findings can guide professional development programs for educators to enhance their knowledge and pedagogical practices in this area. As a result of these research-based studies, researchers in the science field can conduct additional research to develop more effective and enriching learning methods.

3. Methods

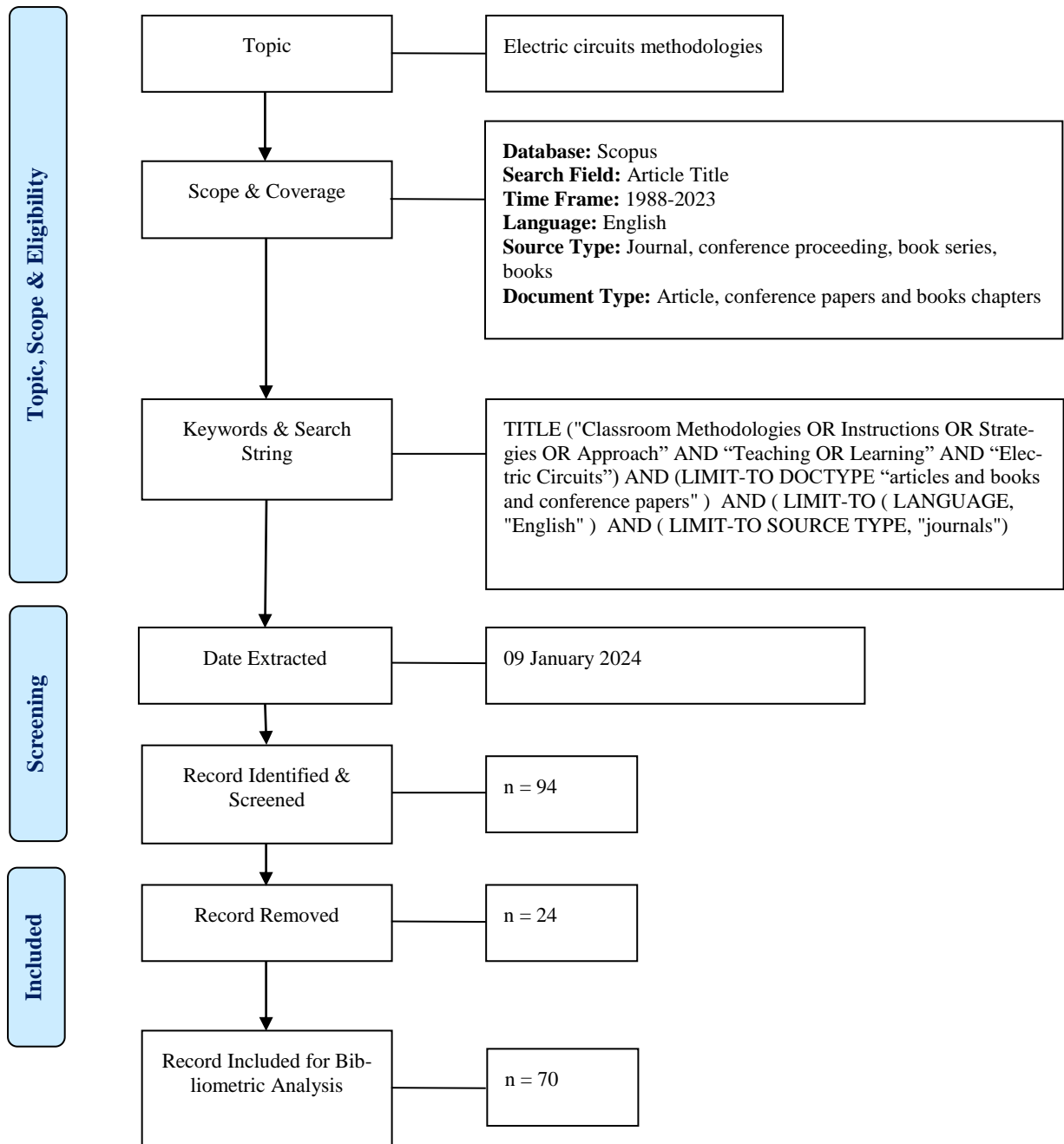
This section presents a bibliometric analysis of electric circuit methodologies and research trends. The current electric circuit research landscape is provided along with a discussion of a potential method and its justification. In addition to providing valuable insights into the existing body of knowledge on electric circuit methodologies and research, these procedures also present a means of identifying key contributors, emerging trends, and knowledge gaps in

the area. It also provides valuable insights into future directions and opportunities for research. Research trends were evaluated using bibliometric methods, which analysed publication outputs of countries, research institutes, journals, research fields, and citation analysis (Cole 1989; Ho, 2008). The methodology involved a bibliometric search of relevant literature in the Scopus database using specific search terms. As shown in figure 1, the researcher derived keywords and search strings from Scopus and replaced them in the search engines of the databases with some synonyms and alternatives (Lozada et al., 2021). In addition to Scopus, other databases were searched for more literature on selected articles. In addition to Scopus, Google Scholar and Web of Science databases were searched to identify the broader field's development status, literature availability, and future directions.

Studies on electric circuit methodologies were quantitatively analysed using the following methods: keyword, and keyword plus, co-occurrences, co-authorships, and citations. A variety of units of counting included documents, sources, organizations, countries, and authors. Each unit of counting in the analysis served a specific purpose, for example, counting sources helped to determine the breadth of research on electric circuit methodologies, while counting organizations and countries provided insights into the global distribution of research efforts. Counting authors and their co-authorship helped identify key contributors and collaborations within the field, and counting citations revealed the most influential and interconnected studies in the literature. Subsequently, findings from selected studies were synthesized to reveal key themes (electric circuits and methodologies), trends, and gaps in the literature. Results of the study would help researchers gain a better understanding of current methodologies and determine future directions for their research.

The bibliometric analysis offered constructive and broad understanding of the current state of knowledge in teaching and learning of electric circuits. A summary of the research strategy is presented in Figure 1.

Figure 1: Flow diagram of the search strategy (Zakaria et al., 2021)



4. Results

The criteria used for selecting the literature or research included relevance to electric circuit teaching methodologies, publication within the specified timeframe, and trend on research standards. A total of 94 records were screened to analyse the statistical properties of the retained literature or research on electric circuit teaching methodologies from 1988 to 2023. The analysis revealed significant variations in the statistical properties of the retained literature on electric circuit teaching methodologies across different time periods and sources. Refer to the Annexure for information regarding the filtering process. Following are the results, as well as types of analysis and counting methods used.

4.1. Document and Source Types

Table 1 summarizes the statistical properties of the initial filtering process that was limited to documents and source types (articles, conference papers, and book and/or book chapters) based on all available methods in the scientific literature.

Table 1: Documents and source type

Source Type	Total Publications (TP)	Percentage (%)
Article	48	51
Conference Paper	18	19
Book series	3	3
Books	1	1
Total source type filtered	70	74
Irrelevant documents removed	24	26
Total documents screened	94	100

The 94 papers were subjected to a literature search that was refined to ensure comprehensive coverage of relevant electric circuit research. For the purpose of gathering a broad range of information, subject areas, key words, countries and territories, and documents were incorporated into the refinement process. This approach helped the researcher to obtain a more holistic understanding of methodologies and research trends in this field. Following the filtration process, 70 source documents were extracted from Scopus and analysed using the VOSviewer software application to identify trends in methodologies and research in electric circuits. As a result of analysing sourced documents from the Scopus database using VOSviewer, the following describes the type of analysis and counting method applied in this study.

4.2. Authorship and co-authorship

Table 2 indicate two authors and one co-authorship who published two documents each that are related to research on electric circuit methodologies, and none of them were linked. Co-authored document was never cited, and O'connell cited more than the other single author.

Table 2: Analysis of keywords

Author	Documents	Citation	Total link strength
Azemi A	2	7	0
Kock Z; Taconis R, Bolhuis S, Grave	2	0	0
O'connell R.M	2	36	0
Total	6	44	0

4.3. Authorship by organization

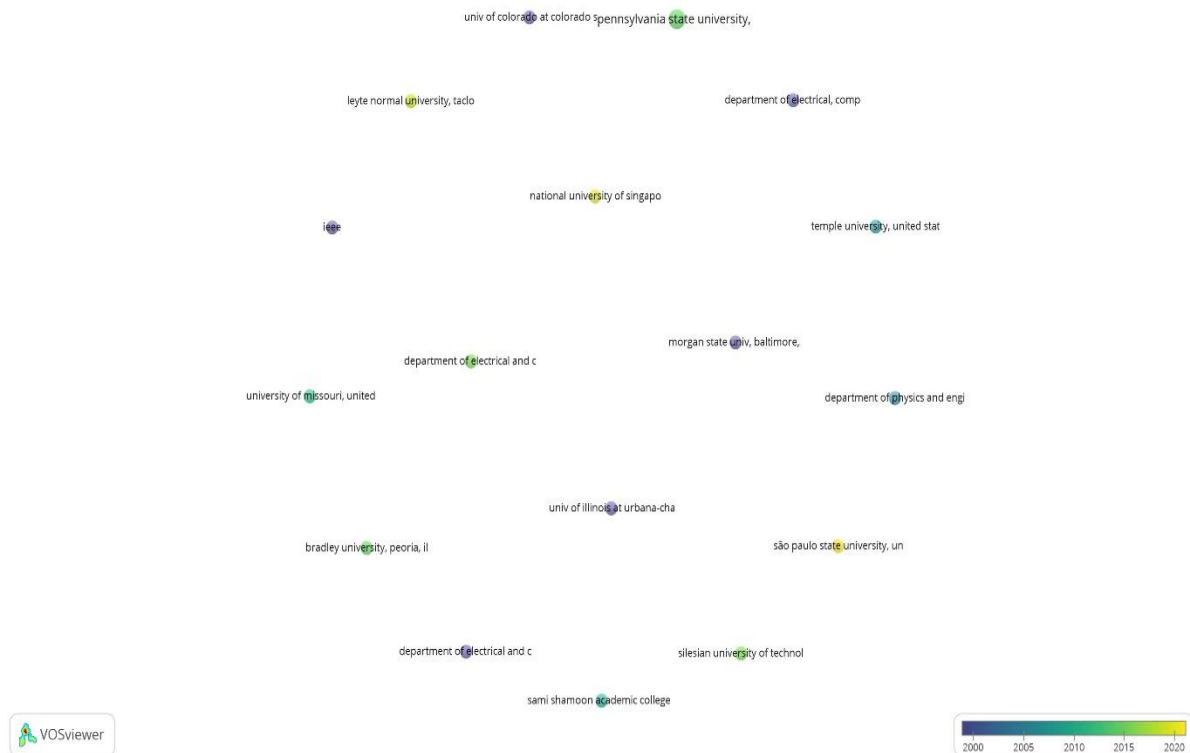
Seventeen (17) organisations were counted, and the total strength of the co-authorship with other organization was calculated. The results indicated only one (1) document published from sixteen (16) organisations and only one organization published two. For all the seventeen (17) organisations that were counted, the total link strength was zero. Table 3 presents the results of authorship by organization, further indicating number of times each document was cited. Only four organizations were cited more than ten times as presented in table 3 in descending order. The remaining thirteen publications were cited less than ten times for a total of 38, four of which were never cited (zero citations). A total of 76 citations from

table below plus 38 citations from the remaining thirteen add to 114 citations all with zero links. Figure 2 present network visualization map of the citation by all 17 organizations that were counted.

Table 3: Analysis of authorship by organization

Organization	Documents	Citation	Total link strength
Department of electrical and computer engineering program	1	29	0
IEEE	1	19	0
Temple university, united state	1	16	0
Department of electrical and computer engineering	1	12	0
Total	4	76	0

Figure 2: Citation by organization network visualization generated using VOSviewer (Van Eck & Waltman, 2020)



4.4. Authorship by country

Seven (7) countries were counted, and the total strength of the co-authorship with other countries was calculated. The results indicated that 18 documents were counted from seven countries, with 114 citations that were not linked. For all the seven (7) organisations that were counted, the total link strength was zero.

Table 4: Analysis of author by country

Country	Documents	Citation	Total link strength
Brazil	1	0	0
Ieee	1	19	0
Israel	2	18	0
Philippines	1	2	0
Poland	1	8	0
Singapore	1	0	0
United States	11	67	0
Total	18	114	0

4.5. Co-occurrence of all key word

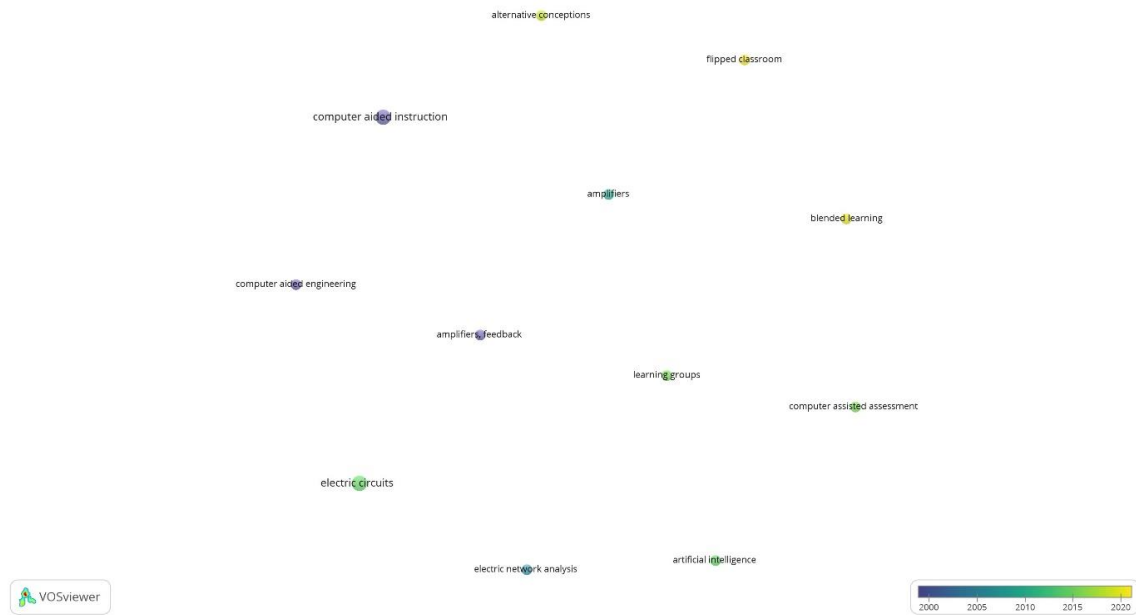
Co-occurrence of all keywords and keywords plus was applied to help the researcher quickly find all records about research related to electric circuits methodologies. The maximum number of co-occurrences of all the keywords extracted twelve documents. Table 4 present all the keywords that were used in this study, and the co-occurrence with zero link strength. Figure 3 present the map visualization of co-occurrence of key word.

Table 5: Analysis of co-occurrences of all the keyword

Keywords	Occurrences	Total link strength
Alternative conception	1	0
Amplifiers	1	0
Artificial intelligence	1	0
Blended learning	1	0
Computer aided engineering	1	0
Computer aided instruction	2	0
Computer assisted assessment	1	0
Electric circuits	2	0
Electric network analysis	1	0
Flipped classrooms	1	0
Learning groups	1	0
Total	13	0

The following is the visual representation of co-occurrences of key words.

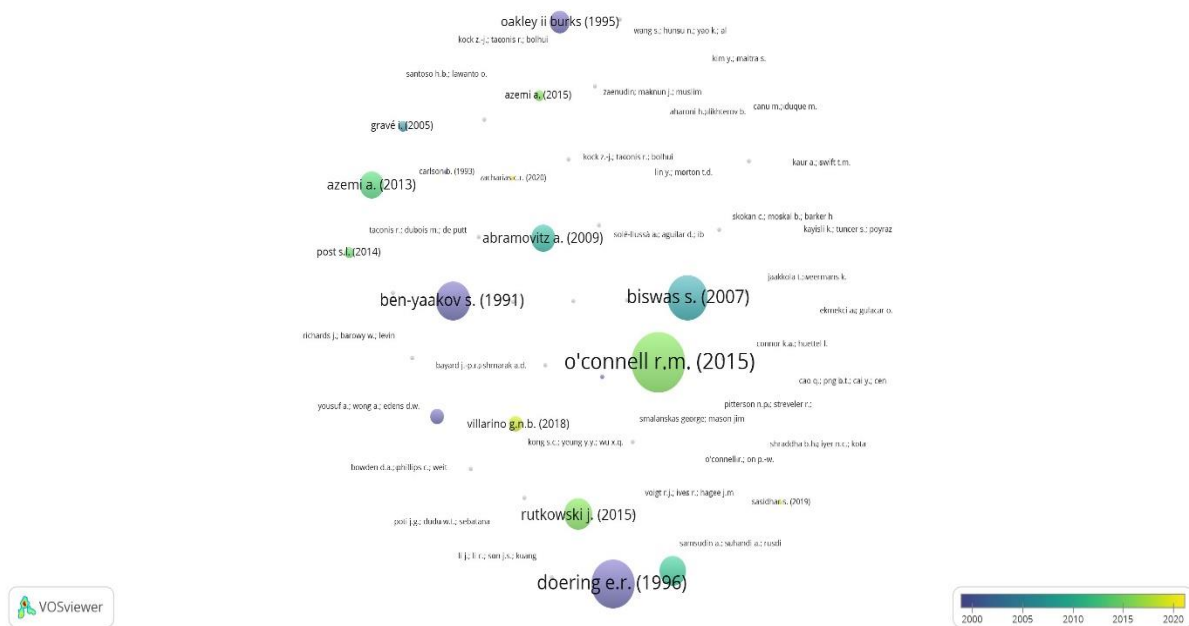
Figure 3: Co-occurrence of all the keywords network visualization generated using VOSviewer (Van Eck & Waltman, 2020)



4.6. Citation by documents

Number of documents that were selected were 70, and the minimum number of citations of a document is zero. The total link strength for all the documents is zero, meaning no links among the documents as shown in the visual map in figure 4.

Figure 4: Citation by documents network visualization generated using VOSviewer (Van Eck & Waltman, 2020)



4.7. Citation from sources

Three documents that were selected are presented in table 5.

Table 5: Analysis of citation of sources

Source	Sources	Citation	Total link strength
Asee annual conference	3	18	0
Ieee transactions on education conference	4	66	0
Proceedings-frontiers in education conference	5	14	0
Total	12	98	0

5. Discussions

According to Lozada et al., 2021, bibliometric analysis is the process of applying statistical methods to evaluate several characteristics of specific bibliographic information. Reviewing the approaches and trends in electric circuit instruction allowed a comprehensive understanding of the existing methodologies and current research status. In this study, Scopus database filter entries revealed only 70 documents in search engine results. The entry date for the search was 1800, and the date range retrieved was 1988 to 2023. A statistical analysis of the retained literature on methodologies for instructing electric circuits revealed no significant differences across time periods. According to this analysis, the lack of exploration into new and groundbreaking research methodologies may have contributed to the stability and consistency observed in electric circuit instruction methodologies over the retrieved dates. There is a possibility that the field may have matured or reached a state of stagnation characterized by established and universally accepted approaches that have withstood the test of time. Stagnation or maturity of a field can have both positive and negative implications. It implies the presence of well-established and effective teaching methodologies, providing a solid foundation for future progress and ensuring consistency in classroom instruction. Conversely, the absence of novel and inventive research methodologies may impede the field's ability to grow and adapt to new challenges, potentially limiting its progress. Consequently, a noticeable scarcity of literature has been observed considering the progress in research on teaching methods and emerging trends in teaching and learning electric circuits.

The inclusion of additional database ensured that potential biases or limitations from relying on a single source were minimized, leading to a more robust and well-rounded analysis. The inclusion of a diverse array of sources was pivotal in this study, facilitating a comprehensive grasp of electric circuits methodologies and research trends. By reviewing a wide range of approaches, the study was able to capture the breadth and depth of the field, enhancing the validity and reliability of the research findings. The review synthesized existing knowledge and methodologies and generate insights of the research trends (Karunaratna et al., 2024).

Journals and scholars from various disciplines have published numerous high-impact articles utilizing bibliometric techniques to study the evolutionary patterns and trends of different fields (Mukherjee, et al., 2022). The exploration of methodologies in the study of electric circuits presented a comprehensive review of current research in science education, engineering, and technology. It addressed a research gap and enhanced the evidence base for further studies. This paper noted the scarcity of research regarding effective teaching strategies for electric circuits in science education. By examining various methodologies and their effects on student learning, the study yielded valuable insights, offering guidance for future research, and informing instructional practices in the field. For an example, a novel method for solving electric circuits was identified to be absent from the study results. The

method is called the table method of solving electric circuits. The absence of the method provided the author with a future platform to conduct study research about this novel method. In the bibliometric review, this method was not found among other methods, and the author recommended that in future research, its effectiveness be tested among science teachers.

Based on Espera & Pitterson (2019), bibliometric review contributes to the advancement of pedagogy and methodology in a field, in this case, teaching electric circuits. As a result of integrating different analysis and counting methods, the researcher was able to gain an understanding of a wide range of perspectives, methodologies, and research trends in electric circuits. The teaching methodologies found in this study included lectures, demonstrations, experiments, problem-solving activities, discussions, and the use of educational technology, such as simulations and virtual labs. These diverse methods aim to foster active learning in electric circuits by engaging students, enhancing their comprehension of intricate concepts, and promoting interaction with complex subject matter.

Although earlier studies focused primarily on conventional teaching methods, recent research indicates a shift toward innovative approaches, reflecting the changing landscape of physics education. Electric circuits have been profoundly impacted by this shift. As a result, students have become more engaged in and have a better understanding of intricate concepts as well as preparing them for the dynamic demands of contemporary life. By conducting bibliometric analysis in this study, a robust analysis was ensured, and a more accurate portrayal of the field was provided.

6. Conclusion

In the initial database search, there was a limited amount of research found, and the resultant number of studies included in this study speaks volumes about the dearth of work in this field. The limited amount of research found in the initial database search indicates a significant gap in the existing knowledge and understanding of electric circuits. This highlights the need for further research to enhance teachers' pedagogical content knowledge (PCK) in this field, as the current body of studies is insufficient to provide comprehensive insights and solutions. Research on methodologies of the teaching and learning of electric circuits is limited and allow space for further research on the teaching and learning of electric circuits.

In the future, science education researchers should explore new innovative methods that can be applied to improving teachers' pedagogical content knowledge (PCK) of electric circuits. Enhancing teachers' pedagogical content knowledge (PCK) in science education can lead to more effective teaching strategies and improved student engagement. Incorporating innovative research methodologies in the study of electric circuits can bring several potential benefits. As a result, new avenues of exploration can be explored, allowing researchers to uncover fresh insights and approaches that can enhance teaching practices and improve learning outcomes. Additionally, innovative methodologies can foster creativity and encourage the development of novel solutions to existing challenges in the field, ultimately driving its growth and facilitating breakthroughs in electric circuit learning and teaching. This will allow teachers to provide targeted support and interventions for students facing challenges when learning about electric circuits. Ultimately, this can contribute to a more meaningful and impactful science education experience for students. Introducing new innovative methods and comparing them with existing methods will provide worthwhile opportunities to learn electric circuits with an understanding of how they operate.

7. Limitations

The limitations of using Scopus as the sole data source may have inadvertently excluded valuable research, hence it was crucial to supplement the Scopus data base with other databases and sources to ensure a comprehensive and unbiased understanding of methodologies and research trends in electric circuits.

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