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Review Article

Teaching and Learning Optics: A Bibliometric Analysis with a Detailed Future Insight Overview

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Abstract

Optics research has recently proven important for scientific, educational, and industrial applications. This study examines the increase and distribution of literature on learning and teaching optics. This analytical strategy uses quantitative and statistical methods to identify trends, evaluate quality, and monitor progress. From the 530 documents obtained using the Scopus database between 1944 and 2023, 464 were chosen. With a total of 49 documents, 2014 had the greatest substantial increase in the number of documents since 1944 till this data was collected. Writers from the United States contributed to 115 documents with 36% citations. They ranked first, followed by authors from Germany (37 documents and 12% citations) and China (36 documents), with citation rankings just below the top 10. Most publications appeared in Physics Education (15 documents; Q2 SJR 0.41). The International Journal of Science Education received the most citations for publications on teaching and learning optics (159 citations; Q1 SJR 1.15) and was ranked 1 in its category. The current core literature on teaching and learning optics shows that this area is quickly evolving but with insufficient international research collaboration. Research collaboration in this field must be strengthened to improve the worldwide response to teaching and learning optics. There is a need to broaden the scope of study regarding assessment instruments, technological engineering, learning approaches, learning methods, learning strategies, and learning media within the context of teaching and learning optics from elementary school to the university level.

1. Introduction

The field of optics has a lengthy and significant history of research findings. These investigations have significantly impacted the scientific, educational, and industrial sectors. Optics research has recently expanded to include studies on superlenses [1-3], liquid glass technology [4-6], optical with metamaterials

[7-9], nano-optical technology [10-13], optics in sensors [14-16], and the advancement of other significant research findings. This state should be seen as a divine gift to all optics researchers, including those in universities, government research facilities, and industry. Optics research prospects can potentially assist society significantly during the next decade. Furthermore, careful mapping of optical content research is required to provide a comprehensive overview of the research progress linked to this area for future development and study.

Optical research mapping has been widely done using bibliometric analytic approaches, notably the Passive Optics Network [17], linear/nonlinear optics properties of thin films [18], distributed optical fiber [19], optics in a knowledge domain and intellectual bases [20, 21], neurological and ophthalmological pathologies [22], development of optical analogues of integrated circuits [23], Water Optics [24, 25], the linear/nonlinear optical properties [26], research performance of Optics [27, 29], Biophotonics in optical technology [30], optical properties of blood [31], the documentary flow on the problems of optics [32], biomedical optics and imaging [33], and Macular Imaging [34]. Nonetheless, numerous new trends in optical research, particularly in teaching and learning, have been recognized but have yet to be mapped using bibliometric analysis. Bibliometric techniques are increasingly being utilized as an analytical tool to demonstrate the growth and effect of studies and assess overall performance in a certain field of study. This research aims to examine the pattern of literature growth and research impact in terms of annual growth, the most productive countries, institutions, and journals, the most frequently cited articles, multi-dimensional research growth using keyword analysis, and research impact in terms of citations.

This research aims to fill research gaps, contribute to the area, and serve as a platform for primary probabilistic research by providing comprehensive information on bibliometric analyses related to optical teaching and learning from elementary school to the university level. The bibliometrically analyzed publications are retrieved from the Scopus database, processed, and categorized depending on the distribution and affiliations of the authors. The typology, geographic distribution, history, primary general sources, alphabetic journal main sources, writers and published materials, and charts may be seen in this analysis. The study topic can be the most critical variable for the research by providing recommendations for future research.

2. Methods

In this study, bibliometric methodologies were applied. The primary goal was to use bibliometrics to evaluate academic productivity in terms of the number of publications and citations generated by a particular academic or institution. Nonetheless, many researchers from many nations have recently used it to characterize the pattern and structure of research development in numerous scientific disciplines based on the presence of research variables/content.

2.1. Data Collection and Analysis Techniques

The scientific publications in this bibliometric study were published in Scopus-indexed journals and conferences. As references, documents that were scientifically reliable and up to date were employed. This investigation, data collection and analysis methodologies were carried out in stages [24, 27] (see Figure 1).

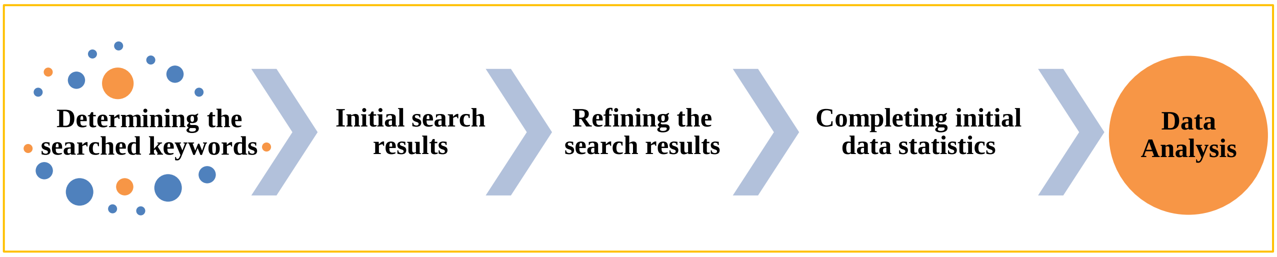

Figure 1. Five steps of bibliometric analysis

When researching a topic, one must first select the search keywords that will be used as the topic of discussion. Paying attention to the topics being researched in the field under study might aid in selecting search terms. This study metadata search was carried out in March 2023 utilizing the author's keywords, "teaching and learning optics". Scopus database search was utilized to obtain metadata.

The first keyword search yielded the first set of search results. The initial search results display the number of articles with relevant keywords. This study employs metadata based on article titles to produce better accurate search results when the "Teaching and learning optics" keyword is typed. As a result, the first data search from the Scopus indexing database yielded 530 documents matching the criteria "source type - Conference Paper, Article, Conference Review, Book, Review, Book Chapter, Letter, Editorial" and "Language - English".

Refinement of search queries is a procedure researchers use to get data with much higher accuracy. This refinement process is based on the document type and then involves re-sorting based on the title and abstract that are more relevant. The initial search results in this study found 464 documents in the Scopus database that were based on journal articles, conference proceedings, review articles, letters, books, and book chapters. These papers were downloaded in CSV and RIS formats to collect all article titles, authors, cities, references, and keywords.

Filling the initial data statistics is a step to fill in gaps in an article's title, year, issue, pages, writer, volume, citation, author's country of origin, publisher, and abstract. The RIS and CSV data formats collected for this study were imported into Mendeley. After the data is full, OpenRefine solves inconsistencies in the data collected to eliminate writing non-uniformity and optimize the analysis findings [39].

Data analysis can be performed if all required data is available. The analysis divides a topic into numerous pieces to make it more straightforward. This study offers a bibliometric analysis of the keyword

"Teaching and learning optics" from a reliable source, namely Scopus. For further detail, all metadata selected and examined with VOSViewer is visualized or mapped using overlay and map visualization.

3. Result and Discussion

The bibliometric review used data from the Scopus.com database. Mendeley software was used to check that the metadata was complete. Following that, the most frequently occurring could be readily checked. The following step was to run VOSviewer software. A bibliometric map of the modified metadata was displayed using VOSviewer. VOSviewer software was used to visualize the network and dictionary density of the bibliometric mapping results.

3.1. Typology

The type of document is the first thing to look at. Data was acquired and sorted from the scopus.com database. Based on the phrase "teaching and learning optics," we discovered at least five publications: journal articles, proceedings (conference articles), review articles, books, book chapters, and letters. Figure 2 depicts the number and percentage of each document type.

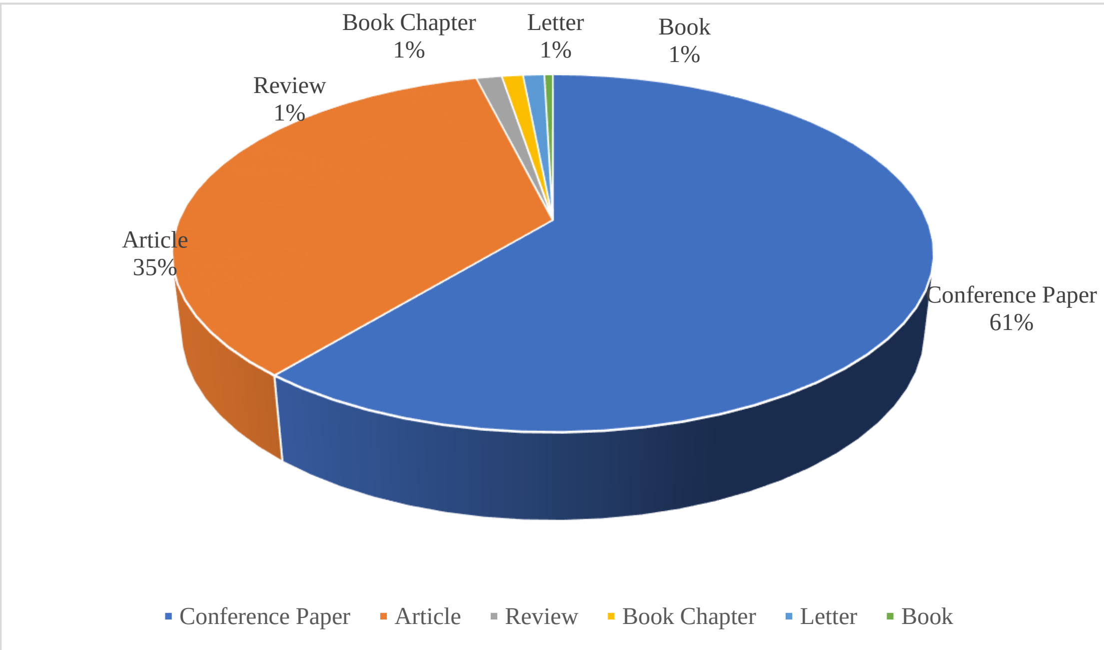

Figure 2. The distribution of data sources by document type

The data in Figure 2 is provided so that users can access the full scopus.com database data on the quantity and proportion of "teaching and learning optics" keywords by "document type". To prevent biasing the information presented, only review articles, proceedings, and journal articles were chosen as the document data to be evaluated with VOSviewer. The analysis derived from these three types of studies can provide more information on bibliometrics using the phrase "teaching and learning optics". The three metadata sources discovered 464 documents relevant to the researcher's keywords based on content type.

3.2. History

The second indication presented and studied is the growth of source documents associated with keywords. The first publication with the keyword "teaching and learning optics" was published in 1944, and it discussed the responsibilities and training of an orthoptic technician [40]. Subsequently, the study of optics education expanded. The number of papers associated with keywords continued to expand till March 2023. Figure 3 depicts the growth (lustrum) during five years.

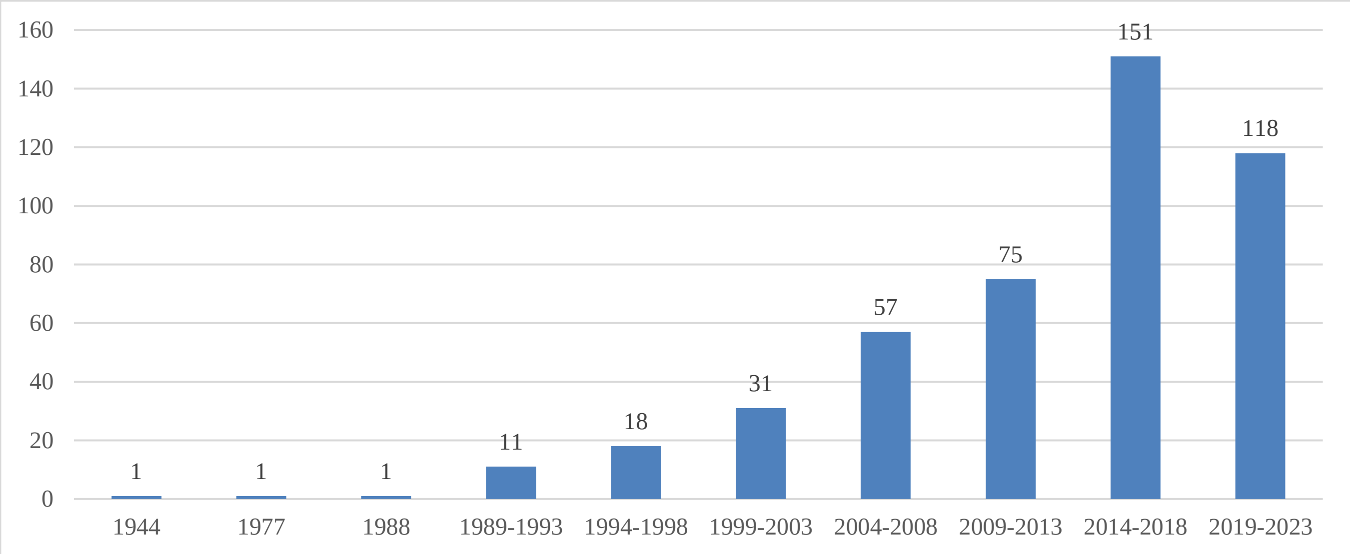

Figure 3. The number of Lustrum documents related to the keyword 'teaching and learning optics' from the Scopus Database

The first significant publication connected to the keywords "teaching and learning optics" was published in 1944 (see Figure 3). It is regarded as a pioneer in studies on optics education and learning. Between 2014 and 2018, there was a significant increase in publishing, with 151 documents. The number of documents could exceed the preceding five-year period from 2019 to 2023 because the temporary aggregate reached 118 papers in the first two months of 2023. As a result, it can be concluded that there is a growing tendency in teaching and learning optical research from year to year.

3.3. Geographic Distribution

The geographical distribution analysis depicts the countries in which the authors of the articles live. The calculation solely takes the document's nation of origin into account. Even if multiple authors are from the same country, this is only counted once. This estimate allows each country to enhance its direction in producing articles about "teaching and learning optics". Figure 4 depicts a map of the distribution of the countries of origin of authors investigating related topics.

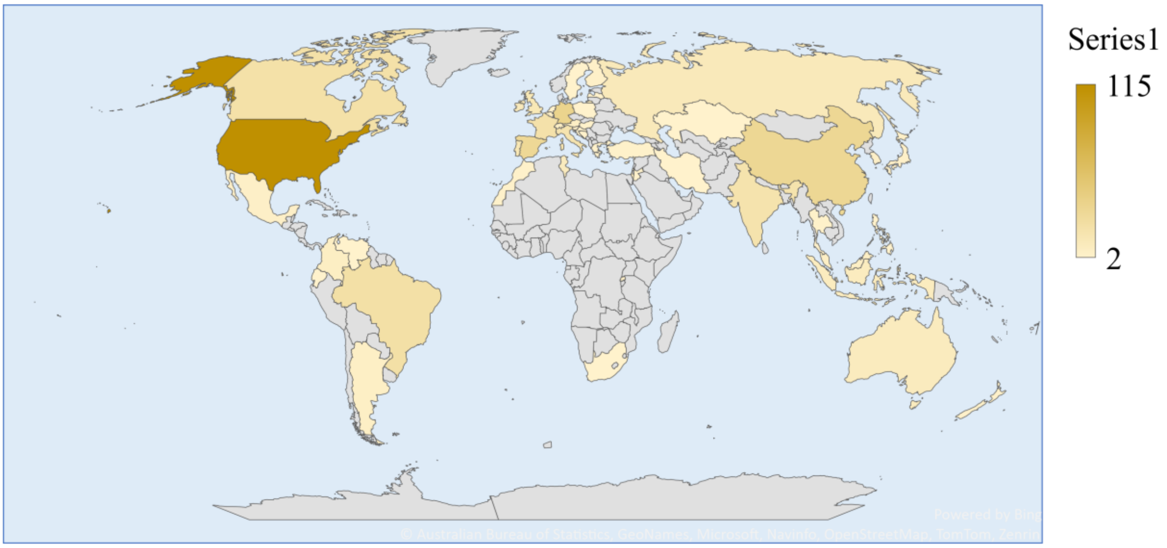

Figure 4. Scopus data for countries regarding teaching and learning optics

According to Figure 4, the deeper shades represent the countries with the most papers. The numbers on the map indicate the top 10 countries with the highest number of documents. The United States is at the top, ahead of 53 other countries, in terms of the number of published articles, with 115. Figure 5 also shows the number of document citations from the nation of origin.

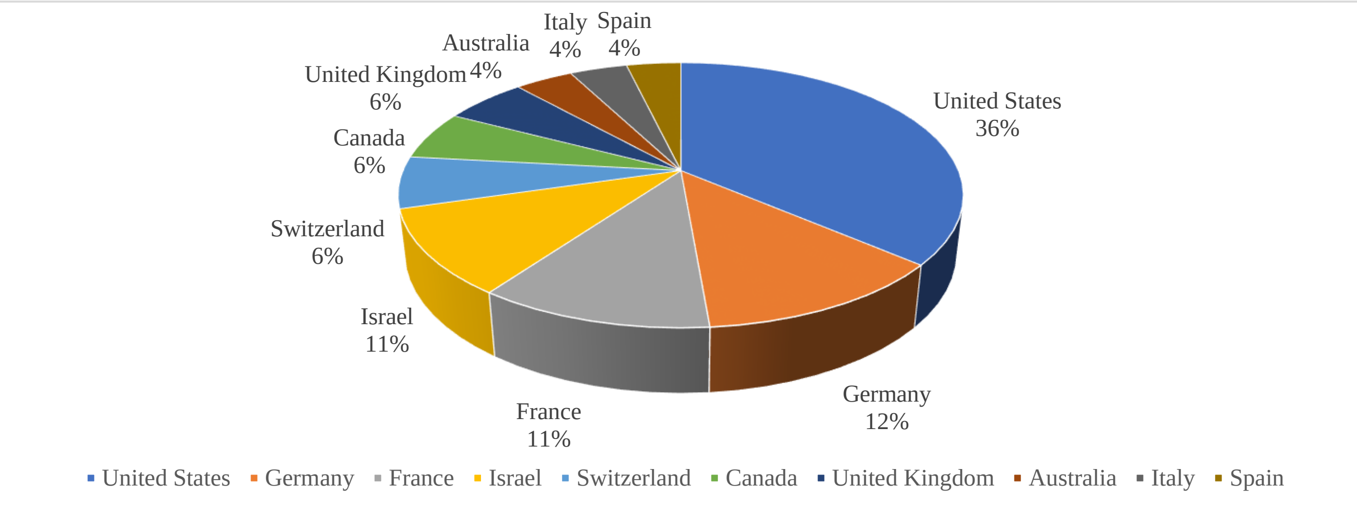

Figure 5. Scopus data for the ten countries with the highest number of citations in teaching and learning optics

Citations show a document's exposure and importance as the primary source in academia, as documents with more citations are deemed more influential in a specific area [41]. According to Figure 5, writers from the United States gain 36% of all citations. Another intriguing finding is that Israel (11%), Switzerland (6%), the United Kingdom (6%), and Australia (4%), which were previously not in the top ten by the number of papers, are now among the top ten by the number of citations. Meanwhile, the three top ten countries with the most documents did not make the top ten with the most citations. It should be noted that the number of citations does not necessarily correspond to the number of texts from a given country because not all documents in a given country are mentioned by other academics.

Citations vary according to the concentration of particular authors in the United States. The total number of citations is 683, with 278 coming from 5 documents. [42] has 68 citations, followed by [43] with 66, [44] with 61, [45] with 47, and [46] with 36. The remaining 110 documents were quoted only 36 times. Figure 6 depicts the distribution of keywords-related articles across all nations and their citation networks.

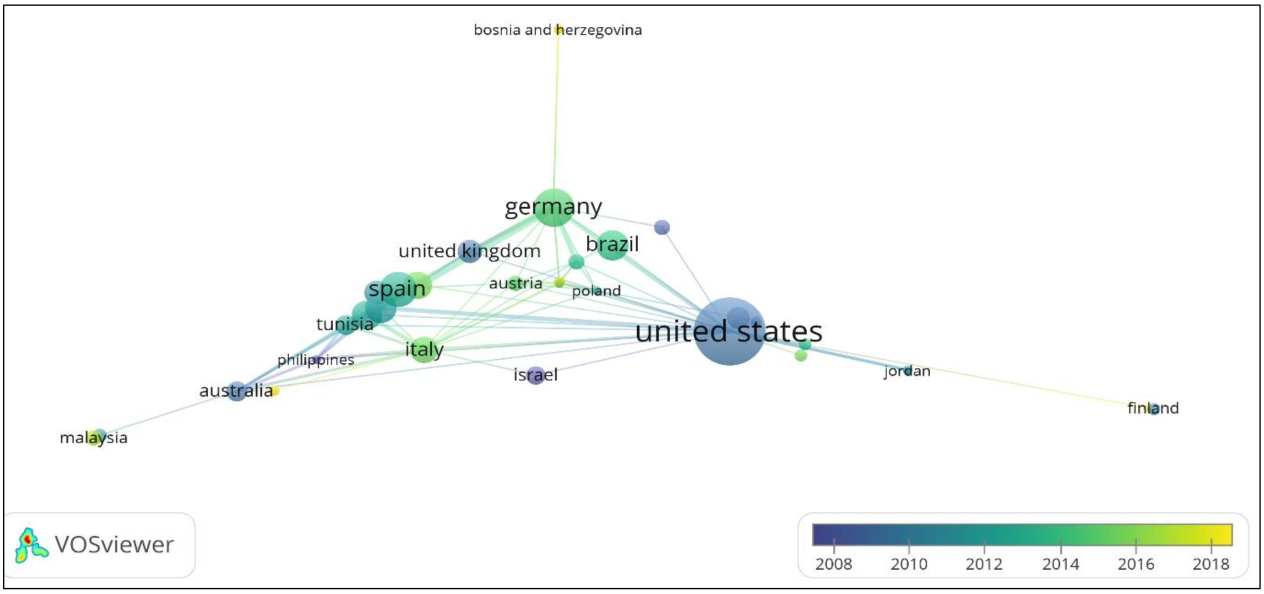

Figure 6. The relationship between countries in terms of the number of documents and distribution of citations associated with keywords

The writer affiliation is used to build the dispersion of the bibliographic network concerning the number of publications and the concentration of citations. Figure 6 indicates that the wider the node circle, the more documents by keyword a country possesses. The thickness of the connecting line shows the number of countries citing the linked country. The United States is at the top, with a total link strength of 35. An intriguing piece of information comes from Germany. Although there are just 37 papers linked to teaching and learning optics, there are 233 citations with a total link strength of 24, making it the second largest behind the United States. The pioneering documents on this issue from several countries are tinted dark purple, including the United States, which released the first document in 1944. While the most recent documents published are highlighted in yellow, they are from Spain, India, the United Kingdom, and Germany.

3.4. Primary Source

The articles were drawn from 100 publications and 34 proceedings. In the primary source section, the focus is on journal papers. Most of these materials are periodicals on teaching and learning optics from diverse scientific domains such as education, medicine, pure science, social science, and environmental science. Table 1 lists the ten journals that published the most articles on teaching and learning optics in schools.

Table 1. Ten journals with the most published documents (teaching and learning optics)

Journal	SJR Index (Scimagojr 2021)	Number of Documents
Physics Education	0,41 (Q2)	15
Revista Brasileira de Ensino de Fisica	0,2 (Q4)	13
European Journal of Physics	0,39 (Q3)	8
Anesthesia	2,5 (Q1)	6
Physics Teacher	0,43 (Q2)	6
Journal of Science Education and Technology	1,15 (Q1)	5
New Physics: Sae Mulli	0,18 (Q4)	5
American Journal of Physics	0,42 (Q2)	4
International Journal of Science Education	1,15 (Q1)	3
IEEE Transactions on Education	0,84 (Q1)	3

Table 1 shows that the bibliographic database by journal source demonstrates that Anaesthesia does not have the most published articles in teaching and learning optics. It does, however, have an SJR of 2.5. This value is the highest of any journal publishing papers with the same keywords. This value indicates how often the article has been cited compared to the published papers. The journal Physics Education has the most documents but has the sixth-highest SJR of 0.41. It is critical to understand the scientific effect of a certain journal. It can serve as the primary reference source for future research. Table 2 shows the classification of journals based on the number of citations.

Table 2. Ten journals with the most citations (teaching and learning optics)

Journal Source	SJR Index (Scimagojr 2021)	Number of Citations
International Journal of Science Education	1,15 (Q1)	159
American Journal of Physics	0,42 (Q2)	117
European Journal of Physics	0,39 (Q3)	106
Anesthesia	2,5 (Q1)	99
Journal of Science Education and Technology	1,15 (Q1)	82
Journal of Research in Science Teaching	2,7 (Q1)	81
British Journal of Anaesthesia	2,64 (Q1)	68
Science Education	2,96 (Q1)	68
Applied Spectroscopy	0,51 (Q2)	63
Physics (Switzerland)	0,51 (Q2)	58

The data in Table 2 come from internationally respected sources and should be the primary reference source in relevant research. Table 2 reveals that the International Journal of Science Education is the top citation journal, with 159 citations obtained from three papers with SJR 1.15 (Q1) [43, 47, 48]. It is worth reviewing, given that just three documents relating to the keywords were published. This journal received the most citations, surpassing Physics Education, which produced 15 publications but did not crack the top ten most cited journals. The papers published in the journal were ground-breaking materials related to the keywords. Other journals that published less than five documents but made the top 10 include the American Journal of Physics in second place, with one of its articles being the most cited [49], the European Journal of Physics in third place with eight documents, and Anaesthesia in fourth place with six documents.

On the other hand, the British Journal of Anaesthesia has only one article but is placed in the top eight for citations. According to the most cited publications, articles published in the British Journal of Anaesthesia rank second. The journal level, the primary reference for keywords in this study, accounts for 60% of the Q1 and 30% of the Q2 levels. In other words, the publications in Table 1 are internationally reputable reference sources deserving of becoming the primary reference source in the relevant study.

The Proceedings of SPIE - The International Society for Optical Engineering has the most citations, with 177 and 172 documents. This means that teaching and learning optics is still being evaluated and researched. The proceedings can identify the most recent trends in research, findings, or technology in a specific subject [50, 51]. Proceedings can be used as a reference source in research, particularly to learn about the most recent trends and discoveries in a field of study. However, using proceedings papers as references necessitates a more in-depth and comprehensive study to explore similar tendencies in other publications, such as journals or books.

3.5. Relevant Authors and Publications

Based on the Scopus database, an author's meta-analysis found that 1215 writers have published papers on this topic. Documents with several authors were divided into different entities. As a result, each author owned rights to many articles, the names of which were also considered. One hundred and seventy-seven authors published at least two documents, with 11 publishing at least five. Figure 7 depicts the information.

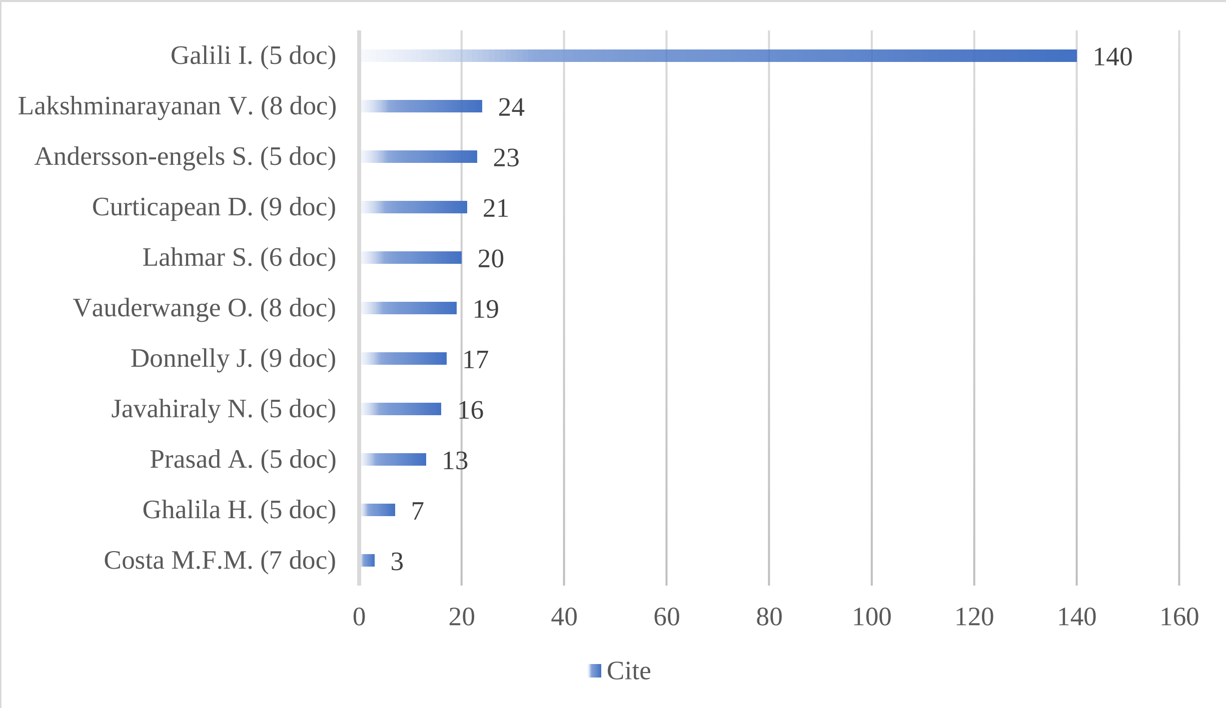

Figure 7. Fifteen most cited authors and documents

Figure 7 depicts the authors' concentration on teaching and learning optics publications. Curticapean and Donnelly are two of the most prolific authors on this subject. These authors each authored nine documents. On the other hand, Author Galili has the most citations, with 140 gathered from 5 documents. Figure 8. depicts an overlay view of the author clusters with at least two documents.

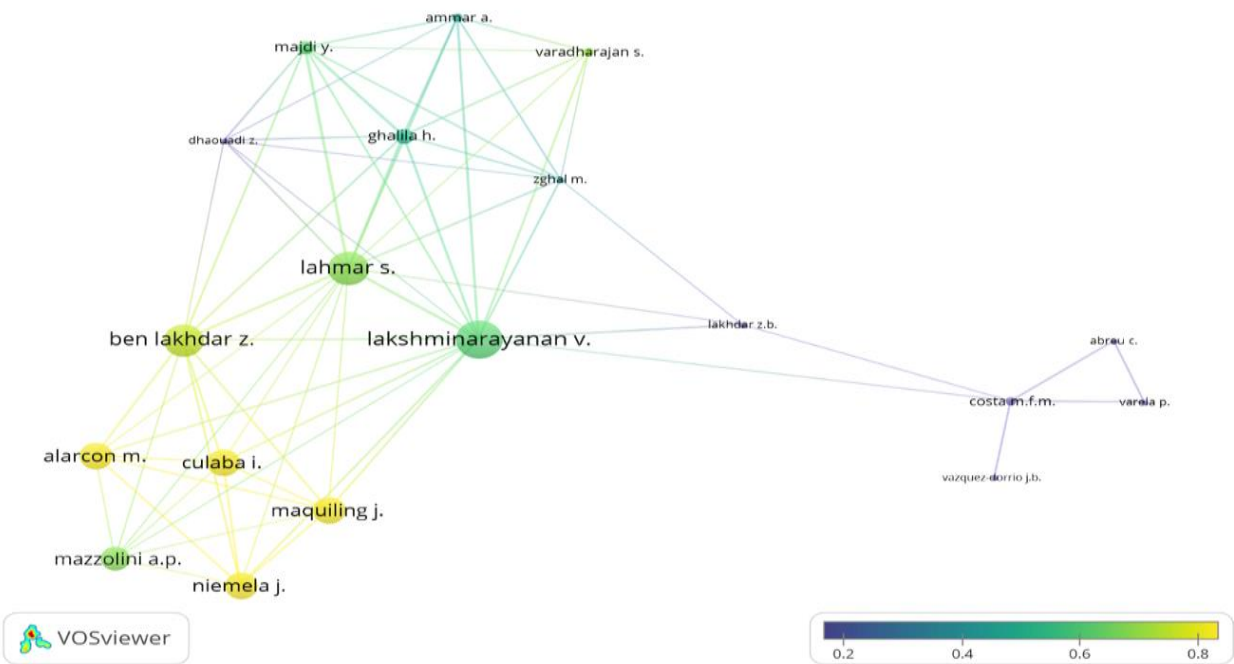

Figure 8. Visualization of overlay distribution of author clusters and impact factors

Figure 8 depicts a graphical overlay of author impact variables that looks to be separated into three clusters. The first cluster (Lakshminarayanan cluster) contains eight related authors, the second cluster (Culaba cluster) contains six authors, and the third cluster (Costa cluster) contains five authors. The colors show the writers' influence factors. Of the other clusters, the Culaba cluster appears to have the highest impact factor.

3.6. Co-occurrence Map with Authors' Keywords Related to Teaching and Learning Optics

The distribution of research subjects related to the core theme of "teaching and learning optics" is interesting. Two hundred and seventy-five relevant keywords were obtained through a VOSviewer analysis (minimum number of occurrences of 2 keywords). The following is a network visualization view (Figure 9) of VOSviewer on the variables and associated statistics on the most frequently recurring keywords and networks in optics education research, starting with the strongest, as shown in Table 3.

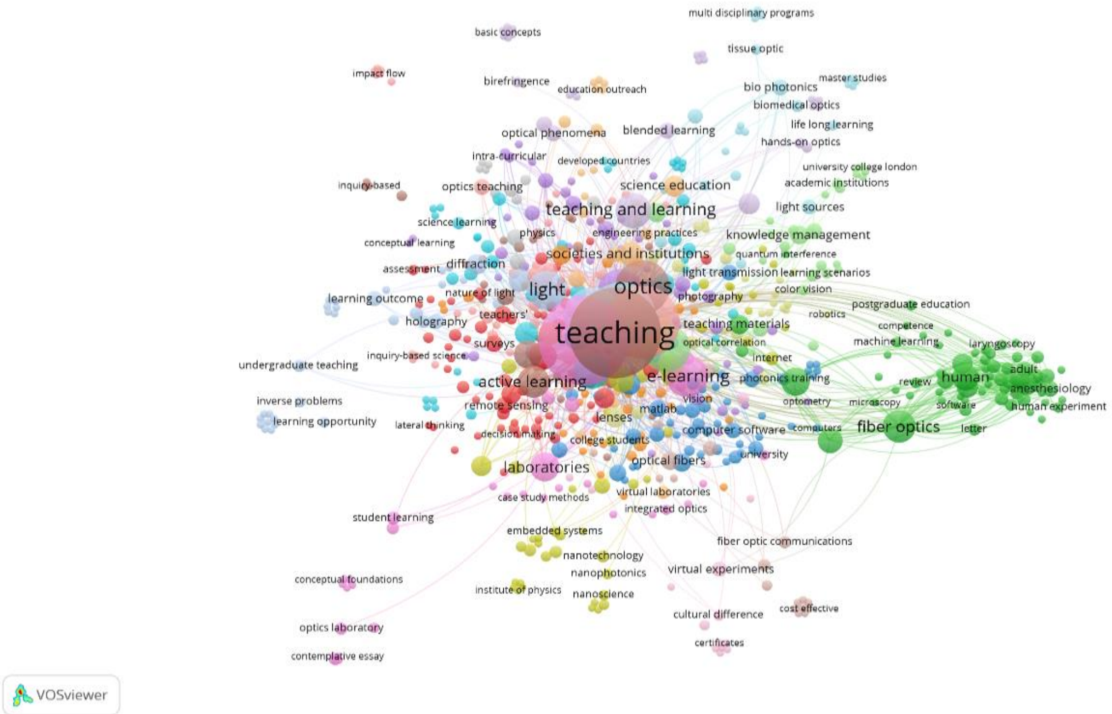

Figure 9. Author co-occurrence visualization network with author keywords

Figure 9 depicts the keyword network with at least two keywords linked to teaching and learning optics. The VOSviewer analysis results are critical, especially regarding useful keywords for future study opportunities [52-58]. Table 3 illustrates, in ascending order, the most often occurring data connected to this issue and the teaching optics research network. The enormous number of "learning and teaching optics" articles produced by various countries provides a bibliometric evaluation of the scope of optics study. In bibliometric analysis, co-occurrence can reveal the association between words or themes frequently appearing in papers [59-63]. The lower a variable's co-occurrence, the less frequently it appears together. This finding can be utilized to open up new avenues for future research. Additionally, the results of this study can serve as a reference for identifying areas that have received considerable attention and those that are still underexplored. Thus, future research in teaching and learning optics will be more varied and contribute to the development of theory, practice, and methodology in optics.

Table 3. Variables most frequently associated with optical education

No	Variables	Co-occurrence
1	Optics	55
2	Education	29
3	Active Learning	24
4	Photonics	24
5	Optics Education	18
6	Geometrical Optics	12
7	E-Learning	11
8	Optics And Photonics	9
9	Training	8
10	Outreach	7
11	Blended Learning	6
12	Critical Thinking	6
13	Distance Learning	6
14	Engineering Education	6
15	Hands-On	6
16	Optical Design	6
17	Physics	6
18	Physics Education	6
19	Teaching And Learning	6
20	Applied Optics	5
21	Biophotonics	5
22	Curriculum Development	5
23	Geometric Optics	5

24	Optical Engineering	5
No	**Variables**	**Co-occurrence**
25	Pedagogy	5
26	Physics Teaching	5
27	Problem-Based Learning	5
28	Professional Development	5
29	Project-Based Learning	5
30	Research-Oriented Education	5
31	Simulations	5
32	Teaching	5
33	Virtual Reality	5
34	Augmented Reality	4
35	Covid-19	4
36	Hands-On Activities	4
37	Higher Education	4
38	Inquiry	4
39	Optics Laboratory	4
40	Remote Learning	4
41	Science Education	4
42	Stem	4
43	Teaching Optics	4
44	Tissue Optics	4
45	University	4
46	Vision	4
47	Wave Optics	4

4. Conclusion

This review examines the metadata of the literature on teaching and learning optics across all levels of education, giving foundational data for future research. As a result, there is an urgent need to broaden the study focus in this discipline regarding teaching and learning optics concerning assessment, learning media, and instructional designs. Finally, teaching and learning optics must be addressed as soon as possible to contribute to technological and industrial breakthroughs. Recent research indicates a lack of worldwide research on collaboration in this subject. The future must establish a global research network between developing and industrialized countries. A network like this will help low-research optical and low-income countries boost their research agendas. A global platform for researchers, educational practitioners, and optics experts to exchange information and develop assessment instruments, engineering technology, learning approaches, learning methods, learning strategies, and learning media in the context of teaching and learning optics from elementary school to university level will also be created as a result of this collaboration.

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