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Top 100 Cited Publications in Physics Education in The last Thirty Years: A Bibliometric Analysis

Nadi Suprapto
Universitas Negeri Surabaya, Indonesia, nadisuprapto@unesa.ac.id

Binar K. Prahani
Universitas Negeri Surabaya, Indonesia

Utama A. Deta
Universitas Negeri Surabaya, Indonesia

Top 100 Cited Publications in Physics Education in The Last Thirty Years: A Bibliometric Analysis

Nadi Suprapto[1,*], Binar K. Prahani[2], Utama A. Deta[3]

[1,2,3]Physics Education Program, Universitas Negeri Surabaya, Surabaya, Indonesia

[*]nadisuprapto@unesa.ac.id

Abstract

The present study's focus is to analyze the top 100 cited papers (classic papers) in the field of physics education in the last thirty years. The study is aimed to provide insight into the citation pattern, authorship pattern, year, journals, countries of these classic papers with the help of bibliometric analysis. The data for the study was extracted from the Scopus database. The study indicated that among these top 100 papers maximum were in the form of research articles. The majority of these top-cited papers were published during the five years from 2012 to 2016. The average citation per paper was calculated to be 34 citations per paper. American Journal of Physics, Science and Education, and Physical Review Physics Education Research are the leading publication sources. Meanwhile, Springer Nature and the American Physical Society dominated publishing the most impactful research in physics education. Kuhn is recognized as the most productive author. Whereas McDermott received the greatest number of citations. The institutions whose authors have contributed the most included the University of Washington and California State University. The USA has predominance over the production of highly cited papers followed by Germany and Spain. Maximum works cited in these top 100 papers have been published within the 50 years from 1971 to 2020. The research areas in these papers are mainly emphasized on physics education, physics, students, computer-aided instruction, and medical education.

Keywords: bibliometrics, physics education, top 100 cited, classic paper

Introduction

Research in physics education has overgrown in the past few decades. For example, the American Journal of Physics (AJP) no longer publishes papers on physics education since 2018, but more than 2,000 papers were published over 80 years, which is considered the best data to examine trends in physics education research (Yun, 2020). The second example is Physical Review Physics Education Research (PRPER); the number of papers in this journal has also been steadily growing since its inception. Generally, it is estimated that the production of scientific publications doubles every 15-20 years (Celeste, Broadbent, & Moyses, 2016; Devi, 2021).

Research is conducted on numerous topics by various authors from different institutions, and knowledge is being advanced through research publications in the form of journal articles, conference proceedings and other media of scholarly communication (Siwach & Kumar, 2015; Suprapto, Prahani, & Deta, 2021; Yanuarti & Suprapto, 2021). However, it is not easy to access the most impactful studies and trending research topics in any field (Yeung, Goto, & Leung, 2017). Bibliometric studies are helpful to identify the research trend and the impactful studies (Parmar, Siwach, & Kumar, 2020; Suprapto et al., 2021). Citation analysis in bibliometric studies is considered a scientific metric measure and use to identify the most impactful research in a field (Devi, 2021; Garfield, 1979). It is an essential tool to measure the impact or influence of that research on the other papers published at relatively low cost (Garfield, 1979; Sengupta, Sarode, Sarode, Gadbail, Gondivkar, Patil, & Patil, 2020). Indeed, some other indirect indicators of quality publication like Scimago Journal Rank (SJR), Impact Factor (IF) and h-index, are also based on the citation count (Devi, 2021; Hirsch, 2005). Thus, the papers receiving more citations are expected to have a good quality of research and influence the knowledge domain in a particular field. Moreover, any paper receiving 100 citations can be considered a classic paper (Heldwein, Rhoden, &

Morgenthaler, 2010).

This study reviewed the trends of research in physics education in terms of the top 100 cited papers to identify the status of physics education research and help researchers in future studies. The study's main objective is to explore the top 100 cited papers in physics education during the period from 1991 to 2020. The specific objectives of the study are as below:

1. To know the types of publications of the top 100 cited papers in physics education.
2. To study the year-wise distribution of the top 100 cited papers in physics education.
3. To identify the sources publishing of the top 100 cited papers in physics education.
4. To study the authorship pattern and prolific authors of the top 100 cited papers in physics education.
5. To identify the institution producing of the top 100 cited papers in physics education.
6. To know the country of origin of the papers and collaboration among them.
7. To study the period of references of the top 100 cited papers in physics education.

Methods

For obtaining the data for the present study, Scopus database was used. The database was searched for the subject category "physics education" using the string given below:

"TITLE (physics AND education) AND (LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017) OR LIMIT-TO (PUBYEAR, 2016) OR LIMIT-TO (PUBYEAR, 2015) OR LIMIT-TO (PUBYEAR, 2014) OR LIMIT-TO (PUBYEAR, 2013) OR LIMIT-TO (PUBYEAR, 2012) OR LIMIT-TO (PUBYEAR, 2011) OR LIMIT-TO (PUBYEAR, 2010) OR LIMIT-TO (PUBYEAR, 2009) OR LIMIT-TO (PUBYEAR, 2008) OR LIMIT-TO (PUBYEAR, 2007) OR LIMIT-TO (PUBYEAR, 2006) OR LIMIT-TO (PUBYEAR, 2005) OR LIMIT-TO (PUBYEAR, 2004) OR LIMIT-TO (PUBYEAR, 2003) OR LIMIT-TO (PUBYEAR, 2002) OR LIMIT-TO (PUBYEAR, 2001) OR LIMIT-TO (PUBYEAR, 2000) OR LIMIT-TO (PUBYEAR, 1999) OR LIMIT-TO (PUBYEAR, 1998) OR LIMIT-TO (PUBYEAR, 1997) OR LIMIT-TO (PUBYEAR, 1996) OR LIMIT-TO (PUBYEAR, 1995) OR LIMIT-TO (PUBYEAR, 1994) OR LIMIT-TO (PUBYEAR, 1993) OR LIMIT-TO (PUBYEAR, 1992) OR LIMIT-TO (PUBYEAR, 1991))"

The data were collected on June 19, 2021. The obtained results were then sorted according to 'times cited' from highest cited to lowest cited. Then the data for the top 100 cited papers was extracted from the database. The data was analyzed with the help of MS-Excel and using the *VOSviewer* software and word cloud generator for visualization (Suprapto et al., 2021a; 2021b; 2021c; van Eck & Waltman, 2020).

Results and Discussion
Publication Type

Table 1. Document types of top cited papers

Document Type	Frequency	Total Citation	Mean	Median	S.D.
Article	77	2763	35.88	22	49.97
Conference paper	11	268	24.36	20	13.32
Review	7	310	44.29	31	42.67
Book Chapter	2	33	16.50	16.5	0.71
Editorial	1	22	22.00	22	-
Short survey	1	13	13.00	13	-
Note	1	13	13.00	13	-
Total	**100**	**3422**	**34.22**	**-**	**-**

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The document types of top 100 publications that have been published in physics education from 1991 to 2020 are shown in Table 1. Among these 100 papers, 77 were in the form of articles, 11 were conference papers, and 7 were review papers. The average citation per document in each category was diverse, with an average is 34. However, the standard deviation for research articles and review papers was high, 49.97 and 42.67, respectively. Meanwhile, the mean citation count of the review was the highest (44.29). In contrast, short surveys and notes were the minor mean citation.

Year-wise distribution of top 100 papers

The top 100 cited articles of physics education have been published during the date range from 1991 to 2019. Maximum among these have been published in the year 2015 (9 articles), followed by the years 2014 (8 articles), 2001, 2013, 2016, and 2019 (7 articles each).

Table 2. Year-wise distribution of papers

Year	Articles	Citations	ACPP	ACPPY	Citable years
1991	1	57	57	1.90	30
1993	2	41	20	0.73	28
1994	2	40	20	0.74	27
1995	1	23	23	0.88	26
1997	1	78	78	3.25	24
1998	3	73	24	1.06	23
1999	1	377*	377*	17.14*	22
2000	3	171	57	2.71	21
2001	7	376	54	2.69	20
2002	3	97	32	1.70	19
2003	2	32	16	0.89	18
2004	2	41	20	1.21	17
2005	5	209	42	2.61	16
2006	6	165	28	1.83	15
2007	4	176	44	3.14	14
2008	3	71	24	1.82	13
2009	1	23	23	1.92	12
2010	3	91	30	2.76	11
2011	2	50	25	2.50	10
2012	5	193	39	4.29	9
2013	7	128	18	2.29	8
2014	8	351	44	6.27	7
2015	9*	155	17	2.87	6
2016	7	149	21	4.26	5
2017	3	67	22	5.58	4
2018	2	55	28	9.17	3
2019	7	133	19	9.50	2
Total	100	3422	34	-	-

ACPP= Average Citation Per Paper, ACPPY= Average Citation Per Paper Per Year, *=the highest number

These top 100 articles received a total of 3422 citations, with an average of 34 citations. The average citation per paper was highest (377) for 1999, while the average citation per paper per year was maximum (17.14) in the same year.

Sources of Publication

Table 3 shows the list of sources that have published the top 100 cited papers in physics education. These top 100 papers have been published in 58 different sources either journals or conference proceedings. The journals "American Journal of Physics" and "Science and Education" are the leading sources publishing seven papers. Meanwhile, six papers were published in "Physical Review Physics Education Research" while five papers were published in "Physical Review Special Topics - Physics Education Research", as the former name of this journal. The top cited papers were also appeared in JSET, IJSE, Physics Teachers, Physics Education, and *Physica Medica* journal. As regards the publishers of these 58 sources, 13 are published by Springer Nature, 11 by the American Physical Society, seven by the American Association of Physics Teachers, and six by Taylor & Francis. The remained publishers are American Institute of Physics (AIP), Institute of Physics (IOP), and Wiley-Blackwell.

Table 3. Sources of top cited papers

Sources	Publisher	Articles	Citations	ACPP
American Journal of Physics (AJP)	American Association of Physics Teachers	7	742	106
Science and Education (S & E)	Springer Nature	7	283	40
Physical Review Physics Education Research (PRPER)	American Physical Society	6	119	20
Physical Review Special Topics - Physics Education Research (PR-PER)	American Physical Society	5	270	54
Journal of Science Education and Technology (JSET)	Springer Nature	4	101	25
International Journal of Science Education (IJSE)	Taylor & Francis	4	128	32
Physics Teacher	American Institute of Physics	4	108	27
Physics Education (PE)	Institute of Physics Publishing	4	104	26
Physica Medica (PM)	*Istituti Editoriali e Poligrafici Internazionali*	4	58	14
Science Education (SE)	Wiley-Blackwell	3	175	58
International Journal of Science and Mathematics Education (IJSME)	Springer Nature	2	67	34
Physics Today	American Institute of Physics	2	150	75
Journal of Science Teacher Education (JSTE)	Taylor & Francis	2	28	14
IEEE Antennas and Propagation Magazine	IEEE	2	31	16
Other sources (with one paper each)	-	44	1058	24
Total	**-**	**100**	**3422**	**34**

The paper published in "Physica Medica" has exponential growth; all the papers published in the source are from 2012 to 2020. In the case of "Physics Education" by IOP has exponential growth, all the papers published in the source are from 2015 to 2020. Meanwhile, for papers published in other journals, the number tends to be constant; some even fluctuate, such as Physics Today and Physics Medica (1991-2002).
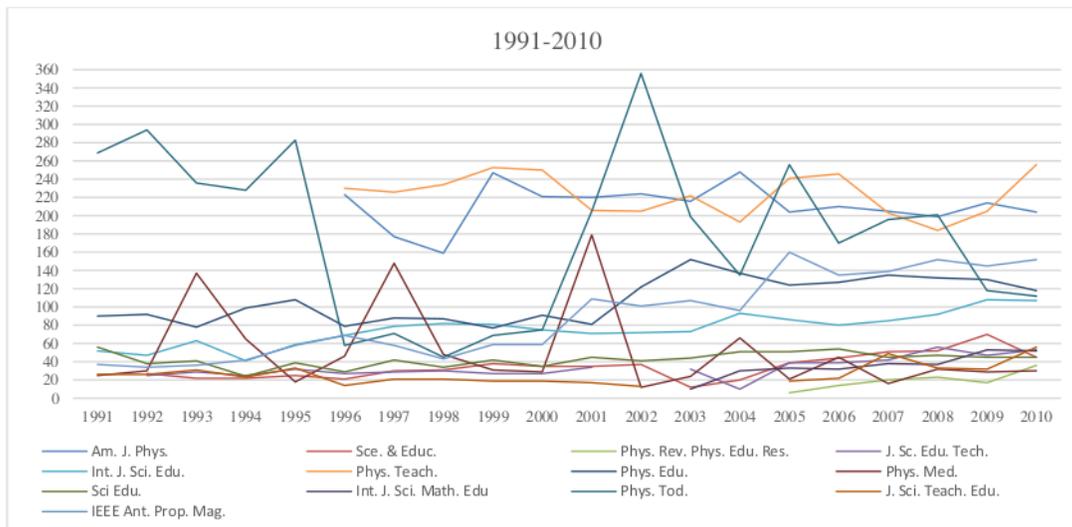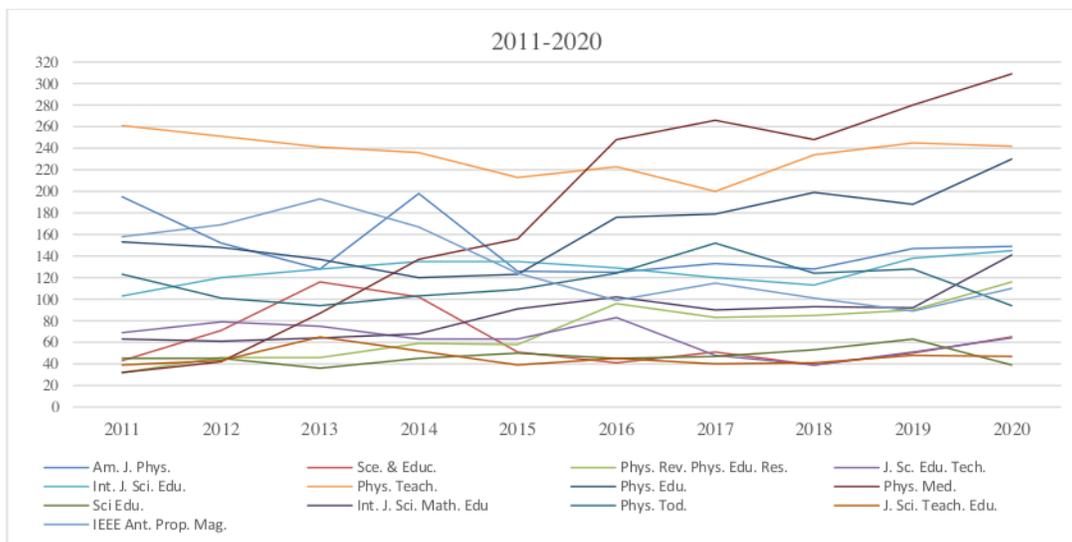

Figure 1. Source growth (1991-2010)

Figure 2. Source growth (2011-2020)

Authors of top 100 papers

Total 227 authors were associated with these 100 top-cited papers in education. Table 4 lists the most prolific authors along with their papers and citations. Nineteen such authors have published more than one top-cited paper, and these authors have contributed to 19 articles as the first author. Kuhn J is recognized as the most productive author, publishing five papers. At the same time, McDermott LC received the most significant number of citations (604) and the most remarkable link strength (11). Top authors' clusters and author production over time are illustrated in Figure 3. Accordingly, there were two major clusters of authors in classic paper in physics education, namely McDermott cluster and Maestre cluster.

Table 4. Author profiles

Authors	Total Articles	Total Citations	Total link strength
McDermott LC	3	604*	11*
Redish EF	2	393	10
Mestre JP	2	213	7
Heron PRL	2	48	5
Caballero RD	2	43	4
Eudaldo T	2	33	4
Olsen K	2	33	4
Kuhn J	5*	123	3
Meltzer DE	2	46	3
Vogt P	2	47	3
Caruana CJ	3	42	2
Christofides S	2	25	2
Koponen IT	4	179	2
Nissen J	2	24	1
Van Dusen B	2	24	1
Mujtaba T	2	68	0
Reiss MJ	2	68	0
Sevgi L	2	31	0
Vollmer M	2	97	0
Other authors with 1 paper each	208		

Based on the single article, the following are the top three of articles that got most citations:

1. Resource Letter: PER-1: Physics Education Research by McDermott and Redish (1999) in American Journal of Physics (377 citations).
2. Oersted medal lecture 2001: "Physics education research - The key to student learning" by McDermott (2001) in American Journal of Physics (201 citations).
3. Synthesis of discipline-based education research in physics by Docktor and Maestre (2014) in Physical Review Special Topics - Physics Education Research (168 citations).
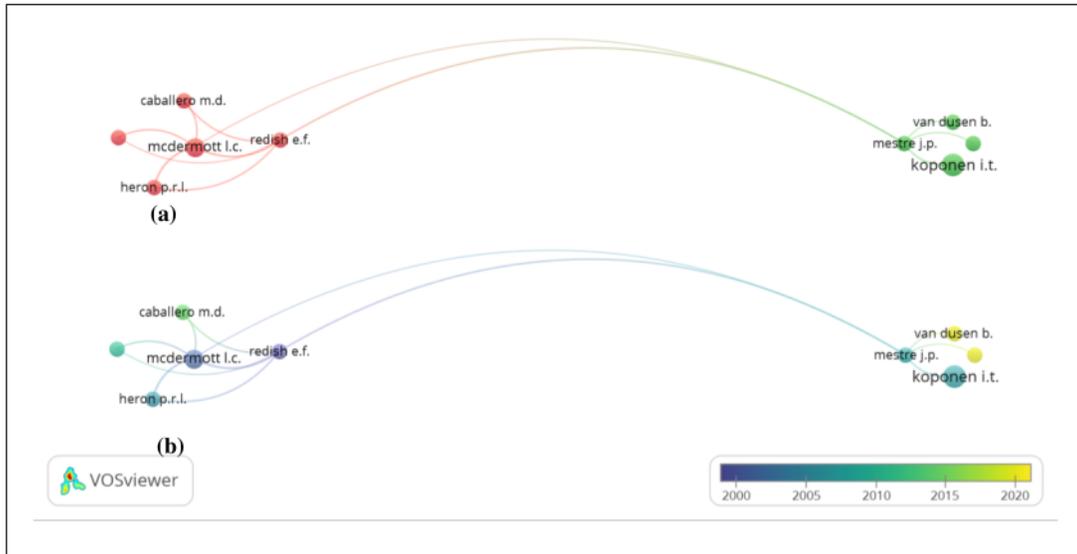
Figure 3. (a) Top authors' cluster; (b) Author production over time

Most Relevant Affiliations and Countries

The top-cited papers in the present study are affiliated with 181 institutions from 33 different countries. Figure 3 shows the most relevant affiliation[20] The University of Washington with 227 citations, California State University with 24 citations, Hospital *de la Santa Creu I Sant Pau*, Spain with 33 citations, has two papers each.
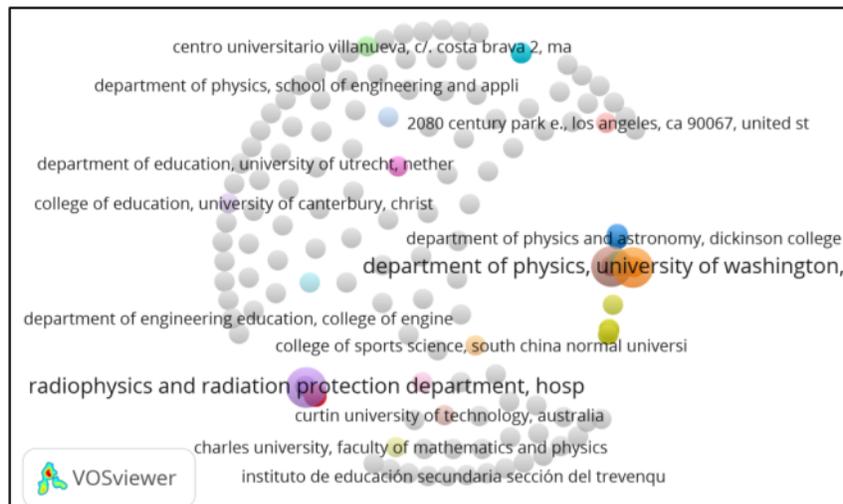

Figure 4. Most relevant affiliations

Table 5. Country of Publication

Country	Articles	Total Citations	Average Article Citations	Total link strength
USA	37	1725	46.62	10
Germany	13	438	33.69	4
Spain	8	149	18.62	6
Finland	7	263	37.57	2
UK	6	163	27.17	1
Indonesia	6	112	18.67	1
Netherlands	5	140	28.00	0
Turkey	4	77	19.25	0
Denmark	4	55	13.75	7
Australia	3	65	21.67	0
Malta	3	42	14.00	2
Canada	2	60	30.00	0
Italy	2	59	29.50	3
China	2	49	24.50	0
Sweden	2	36	18.00	4
Israel	2	36	18.00	1
Cyprus	2	25	12.50	3
Austria	2	24	12.00	0

For calculating the country of publications, only the first author was considered. Table 5 indicates that 18 different countries have produced the top 100 papers. USA has predominance over the production of highly cited papers with 37 papers, followed by Germany (13 papers), Spain (8 papers), Finland (7 papers), and the UK and Indonesia (6 papers each). The illustration of the most relevant countries is illustrated in Figure 5.
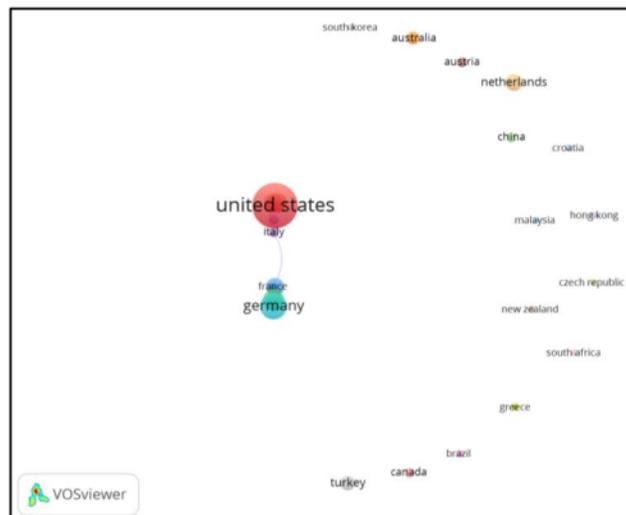

Figure 5. Most relevant countries

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Table 6. References time span of top papers

Year of References	No. of References	% Age
1891-1900	13	0.29
1901-1910	17	0.38
1911-1920	20	0.45
1921-1930	11	0.25
1931-1940	10	0.23
1941-1950	16	0.36
1951-1960	26	0.59
1961-1965	27	0.61
1966-1970	27	0.61
1971-1975	47	1.06
1976-1980	89	2.01
1981-1985	187	4.23
1986-1990	327	7.39
1991-1995	491	11.10
1996-2000	733	16.58
2001-2005	691	15.63
2006-2010	846	19.13
2011-2015	674	15.24
2016-2020	170	3.84
Total	**4422**	**100.00**

Among all the countries producing highly cited papers, the articles from the USA have received the highest number of citations (1725), with an average citation per paper of 46.62. Meanwhile, Finland performed an average citation of paper of 37.57. The average citation received by each county is around 10 to 50 citations per document.

References

Table 6 illustrates the time of the references of the top-cited papers. The references used in these papers range from 1891 to 2020. Out of the total references, 96%   falls within the time range from 1971 to 2020 or 44% within the time range from 1991 to 2015. The maximum numbers of references (19.13%) belong to 2006-2010. It was observed these papers were produced from 2011 to 2020, and the reference used in this literature is mostly newly emerged within the recent 20 years. The old pieces of literature have also been cited, but that amounts to tiny per cent of the total references. The visualization of the most relevant references is illustrated in Figure 6. Meanwhile, Figure 7 indicates the cited references cluster produced among references time of top papers.
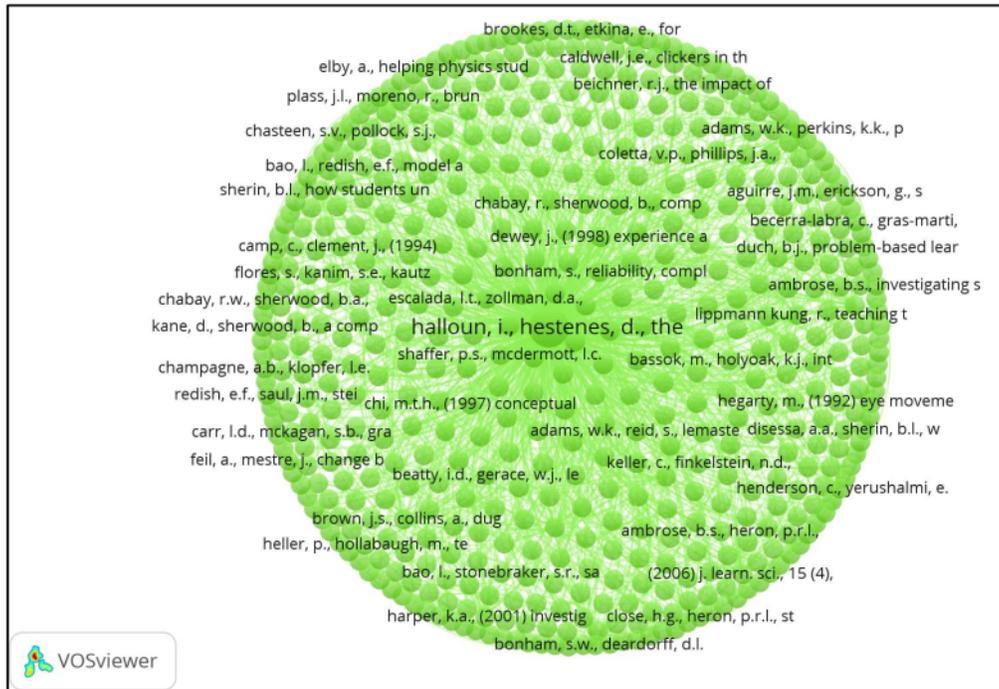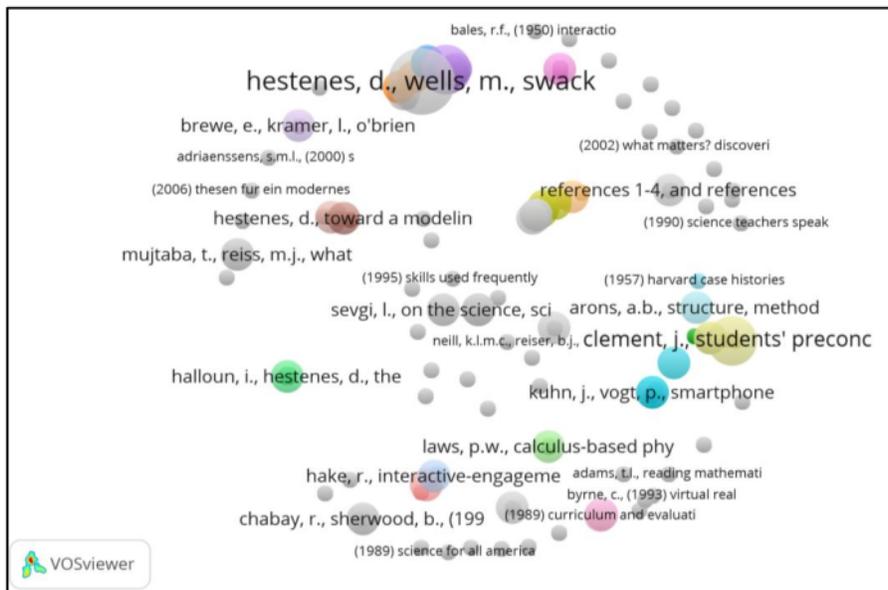
Figure 6. Most relevant references

Figure 7. Cited references cluster

Keywords of the papers

The most frequently used keywords are indicated graphically in figure 8. The font size of the

10

text in the figure represents the frequency of the words used in these papers. The words used more frequently are physics, students, education, physics education, article, medical education, human, curriculum, Europe, and computer-aided instruction.
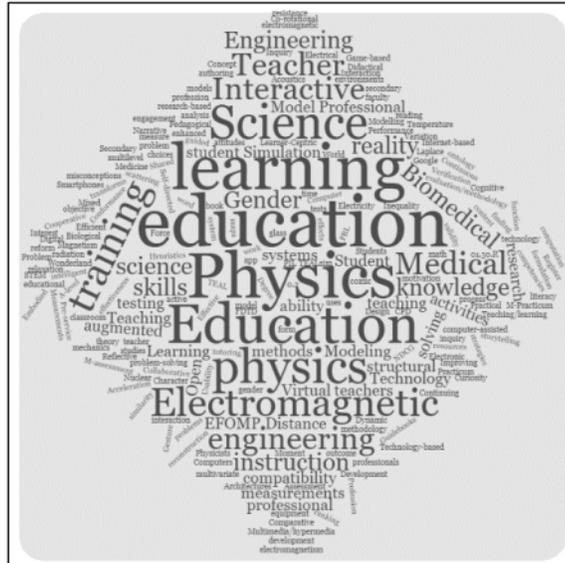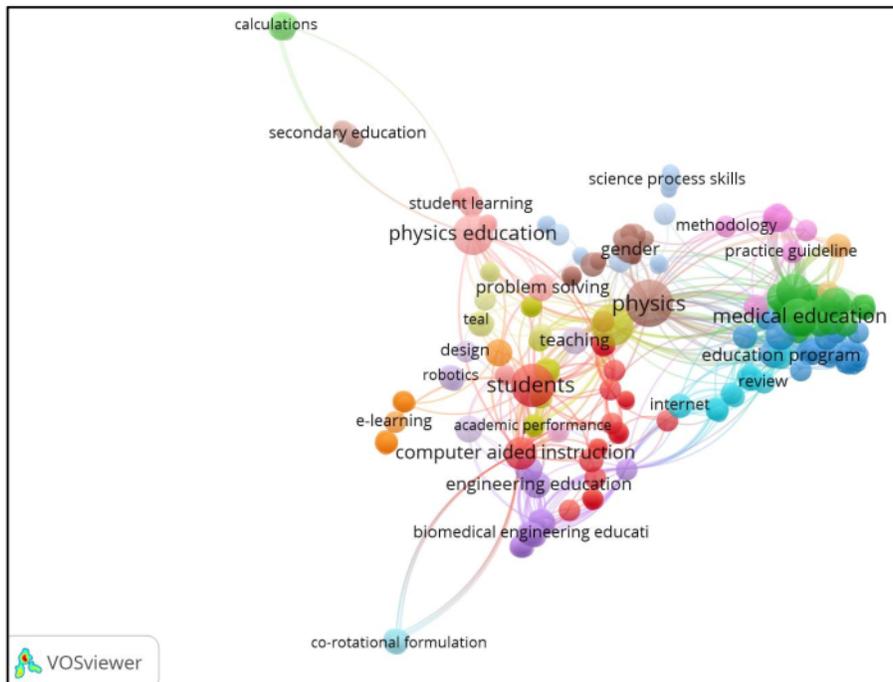

Figure 8. Most relevant keywords

Figure 9. Keyword co-occurrence

Keyword co-occurrence

The keyword co-occurrence network in Figure 9 is based on the most frequently occurred keyword-plus words with a minimum of 5-edge points. Twenty-five such keywords are identified. This keyword co-occurrence network provides a brief insight into the areas/topics on which the research has been conducted. The map identified ten such clusters with some common words among these clusters: physics, students, physics education, teaching, medical education, problem-solving, engineering education, etc. The size of the text represents the more frequently used words. The primary cluster among all these clusters has five keywords; the clusters suggest that many researchers have conducted on "physics education", "physics", "students", "computer-aided instruction", "medical education". Some other clusters mainly focus on science process skills, gender, problem-solving, e-learning, etc.

Conclusion

This paper is the first of its kind bibliometric study of 100 top-cited papers in the "physics education" field. The study data consisted of top 100 publications in physics education from 1991 to 2020 obtained from the Scopus database. It was found that among these top 100 papers maximum were in the form of research articles, followed by conference papers, and a few were review papers. The majority of these top-cited papers were published during the five years from 2012 to 2016. The average citation per paper was calculated to be 34 citations per paper. The journals "American Journal of Physics", "Science and Education", and "Physical Review Physics Education Research" are the leading sources of publication and Springer Nature, American Physical Society, American Association of Physics Teachers, and Taylor & Francis has dominance in publishing most impactful research in physics education. The majority of the research papers were multi-authored. Kuhn J is recognized as the most productive author. At the same time, McDermott LC received the most significant number of citations and the most incredible link strength. The institutions whose authors have contributed the most included the University of Washington, California State University, and Hospital *de la Santa Creu I Sant Pau*, Spain. The USA has predominance over the production of highly cited papers followed by Germany and Spain. Maximum works cited in these top 100 papers have been published within the 50 years from 1971 to 2020. The research areas in these papers are mainly emphasized on physics education, physics, students, computer-aided instruction, and medical education.

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