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The impact of emerging technology in physics over the past three decades

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ABSTRACT
As humanity reaches the 5.0 industrial revolution, education plays a critical role in boosting the quality of human resources. This paper reports bibliometric research on emerging TiP during 1993-2022 in the educational field to analyse its development on any level of education during the last three decades. This study employed a Scopus database. The findings are that the trend of TiP publication in educational fields has tended to increase every year during the past three decades and conference paper became the most published document type, the USA is the country which produces the most publications; 'Students' being the most occurrences keyword and total link strength. The publication of the TiP is ranked to the Quartile 1, which implies that a publication with the cited performance is a publication with credibility because the publisher has a good reputation. Researchers can find the topics most relevant to other metadata sources such as Web of Science, Publish, and Perish.

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Introduction

As humanity enters the 5.0 age, education will be critical in boosting human capital quality. Society 5.0 is a stage of civilisation that addresses various technical and social problems using advanced technologies produced during the industrial revolution's 4.0, including Artificial Intelligence (A.I.), robots, internet of Things (IoT), and Big Data (large amounts of data) to improve the quality of human life (Kahar et al., 2021). Society 5.0 is human-centered but technologically based (Hamdani et al., 2019; Islam et al., 2020). However, technology-based platform's influence differed since pupils viewed the constructed elements variously (Christopulos & Sprangers, 2021).

Physics is one of the subjects with a high opportunity for implementing technology in its teaching and learning. The digitisation of critical thinking skills in physics learning is an on-going trend (Jatmiko et al., 2021). Since it needs innovative learning in applying IT-based learning (Koç & Büyük, 2021; Morales et al., 2022; Negoro et al., 2023), IT-based physics education can stimulate pupils' active participation, as well as the findings demonstrate a considerable boost in physics (TiP) learning (Aswal et al., 2019; Ferty et al., 2019; Tetep & Dahlena, 2021; Wijaya et al., 2021). The benefit of emerging TiP learning is that pupils may interact with high-quality, actual data like experts do (Damar & Turkey, 2022; Ellermeijer & Tran, 2019; Iatsyshyn et al., 2020; Karim et al., 2020). Physics education using technological devices is similar to practising in interaction with the present study effort (Deveci, 2023; Jumini et al., 2022). Investigations using technological tools are described as demanding, complicated, open-ended, requiring a substantial commitment and a diverse set of abilities (Khan et al., 2022; Van den Beemt et al., 2020; Vesikivi et al., 2020; Wang et al., 2022). However, there are still obstacles and challenges in implementing emerging technology in physics learning (Mwambela, 2019).

Organisations are paying particular attention to advancements in A.I. and robotics because they promise eventual efficiency improvement (Schweikl & Obermaier, 2020), especially in educational fields (Papadopoulos et al., 2020; Raman et al., 2022). Previous research involving a bibliometric investigation has focused on emerging e-books (Dawana et al., 2022), e-module (Dewantara et al., 2021) in physics learning, augmented reality (A.R.)-based in the laboratory of physics (Putri et al., 2021), Prezi mind mapping as media in physics learning (Zakhiyah et al., 2021), and online physics learning in Indonesia (Yani et al., 2021). However, in previous studies, there has yet to be a publication of the bibliometric in emerging technology in physics. This research conducted bibliometric research on publications **(Prahani et al., 2022)** of emerging technology in the physics education field to analyze its actual impact in any level of education during 1993 to 2022.

Research Objectives

This research identifies bibliometrics on TiP keywords in educational fields. The publications indexed by Scopus were used to collect the metadata. This research was to compare trends, patterns, novelty, and future research in TiP over the past three decades. Specifically, the objectives of this research were as follows:

1. To compare trends in research on the TiP publications during 1993-2022.
2. To identify the various type ot TiP publications during 1993-2022.
3. To identify the most used language in TiP publications during 1993-2022.
4. To identify the top 10 most productive countries in terms of TiP publications during 1993-2022.
5. To detect any trend in mapping of TiP keywords network publications during 1993-2022 to finding the novelty, recommendation and implication for further research.
6. To identify the promenint of the sponsorship finding, affiliation and authors during 1993-2022 as recommendation or futher collaboration in TiP research for further researcher.
7. To identify the main subject areas of TiP publications during 1993-2022.
8. To identify the distribution of top cited publication TiP during 1993-2022.
9. To identify the top 5 cited publications in TiP publication research during 1993-2022 as further recommendation to develop the TiP research.
10. To identify the research route in TiP to educational fields for future research

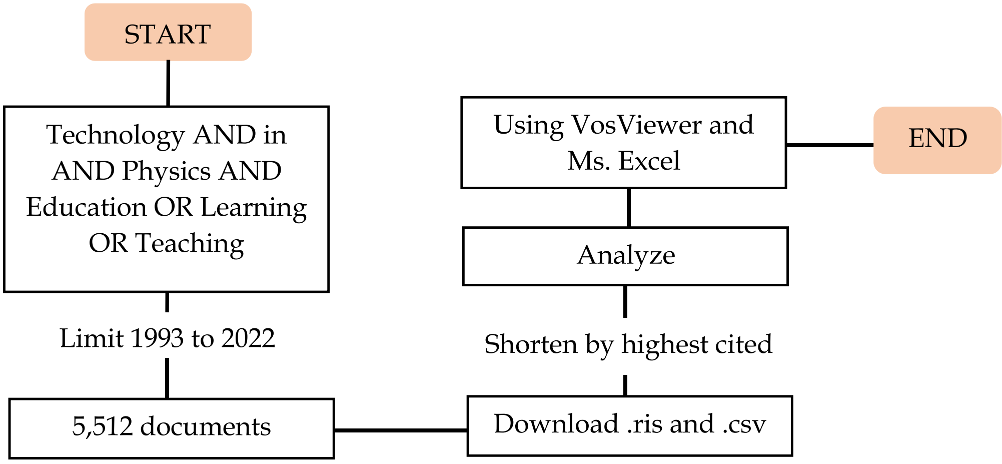
Methods

This study employed a Scopus database (http://www.scopus.com/) since it contains more linked records than other sources (Phuong et al., 2022). Bibliometric analysis assists researchers in determining long-term trends (Schöbel et al., 2021; **Abdullah, 2022**). Furthermore, bibliometric analysis scientists' contributions, interactions, and the annual increase in publications and citations

(Do et al., 2021; Prahani et al., 2022; Yanniris & Huang, 2018). The steps of this research were as follows: (1) developed a research plan, (2) acquired information examination objectives, (3) data processed, and (4) summarised and presented information (Moral-Muñoz et al., 2020; Prahani et al., 2022). The flowchart of this research to determine the emerging technology in educational physics fields is as in Figure 1.

Figure 1

Research Flowchart



Data were gathered on February 8th, 2023, yielding 6,042 publications, reduced to 5,512 by restricting the timeframe to 1993-2022 by highest to lowest citation. The data was imported to external software for descriptive analysis (Kamarrudin et al., 2022; Marulanda-Grisales & Vera-Acevedo, 2022).

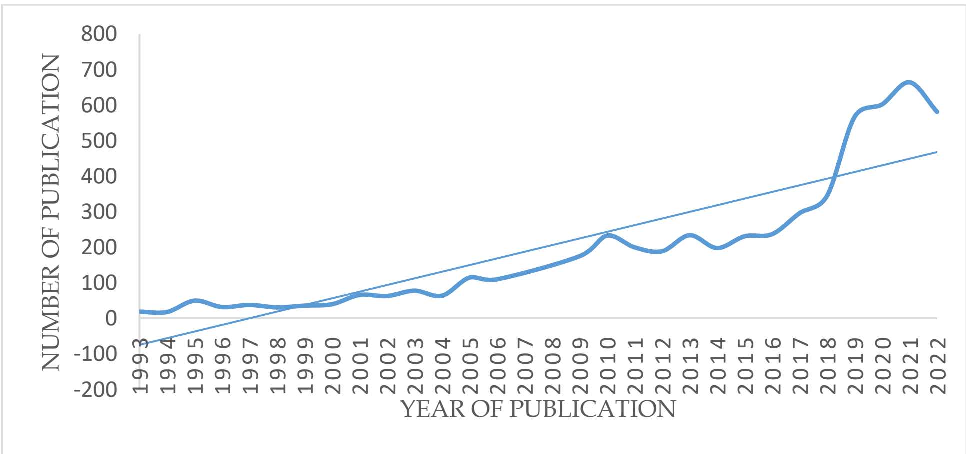
Findings

Types of Documents, and Most Used Language in TiP Publications 1993-2022

Figure 2 depicts the trend in physics (TiP) education during 1993-2022.

Figure 1

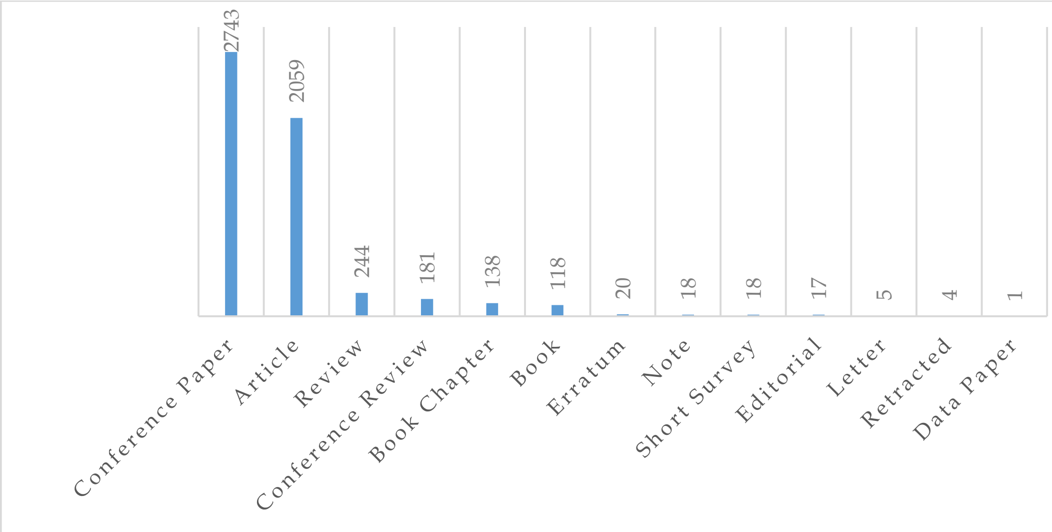
Number Publications of TiP in Educational Fields



The trend of publications in TiP consists of various available documents. Whether all documents were open access or not in any journal website, proceeding, book, book chapters, lecture notes, or more (Kousha & Thelwall, 2020), based on the data gathered, it can be known the various types of documents published from 1993 to 2022 as a deliberation for future researchers. Figure 3 shows the various types of published documents on TiP.

Figure 3

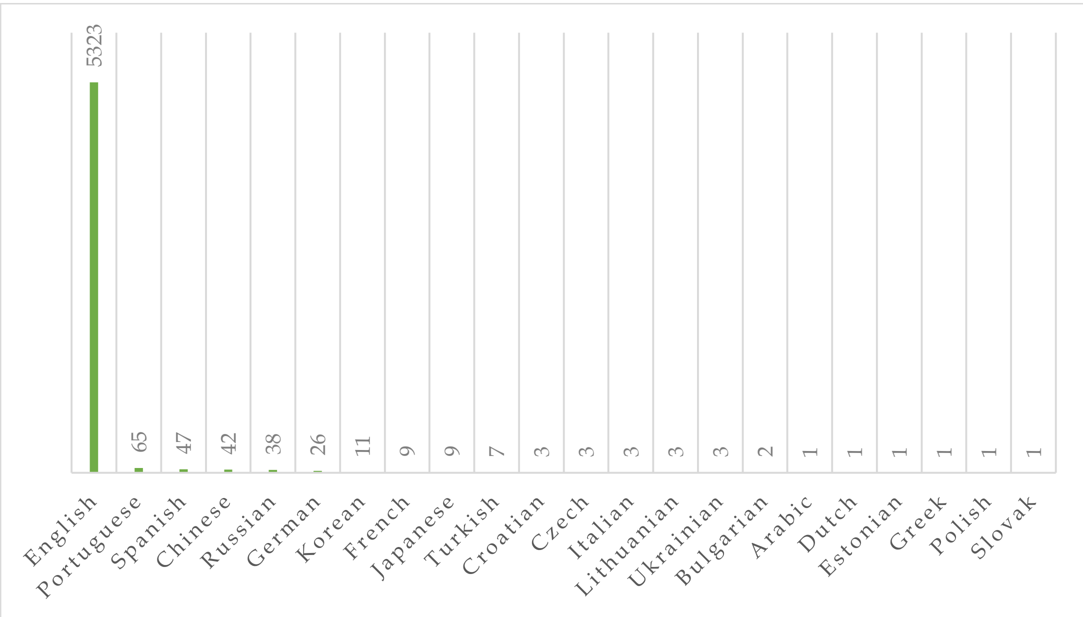
Various Types of TiP Publications in Educational Fields



Based on Figure 3, the conference paper (C.P.) is the most widely used with 2,743 documents. An 'article' is the second most common form of publication in the TiP study, accounting for 2,059 publications. 'C.P.' displayed at a summit for many specialists from various disciplines to see (Gass et al., 2021; Papadakis, 2021). Figure 4 shows the most used language in TiP publication.

Figure 4

The Most Used Langauge in TiP Publication



Top Countries in TiP Publications During 1993-2022

Figures 5 and **6** show the most productive countries in TiP publications can be analyzed using metadata. It is known that 122 countries are being recorded in Scopus.

Figure 5

World Contribution Countries to TiP Publications

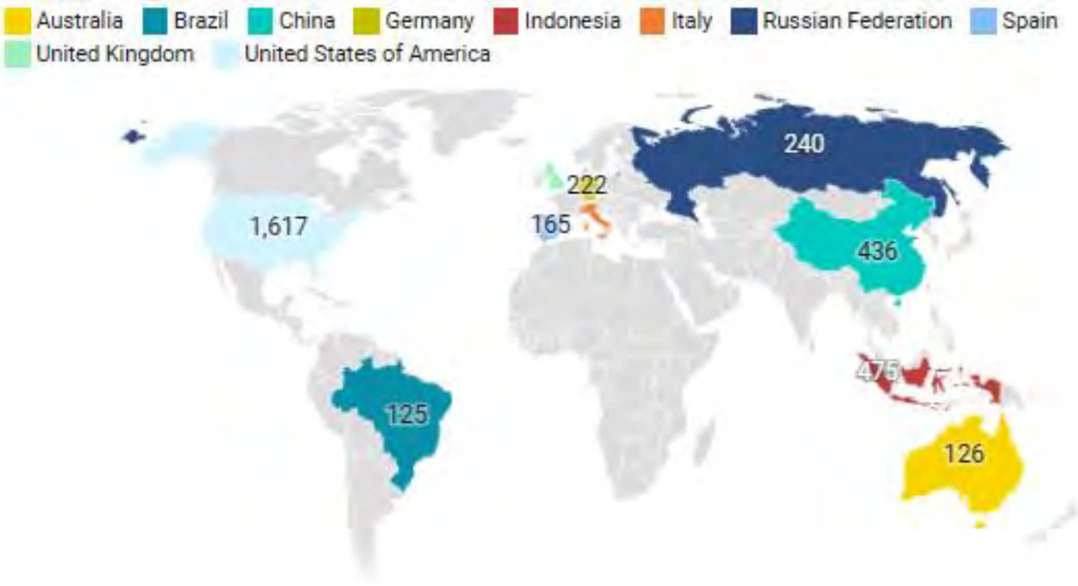
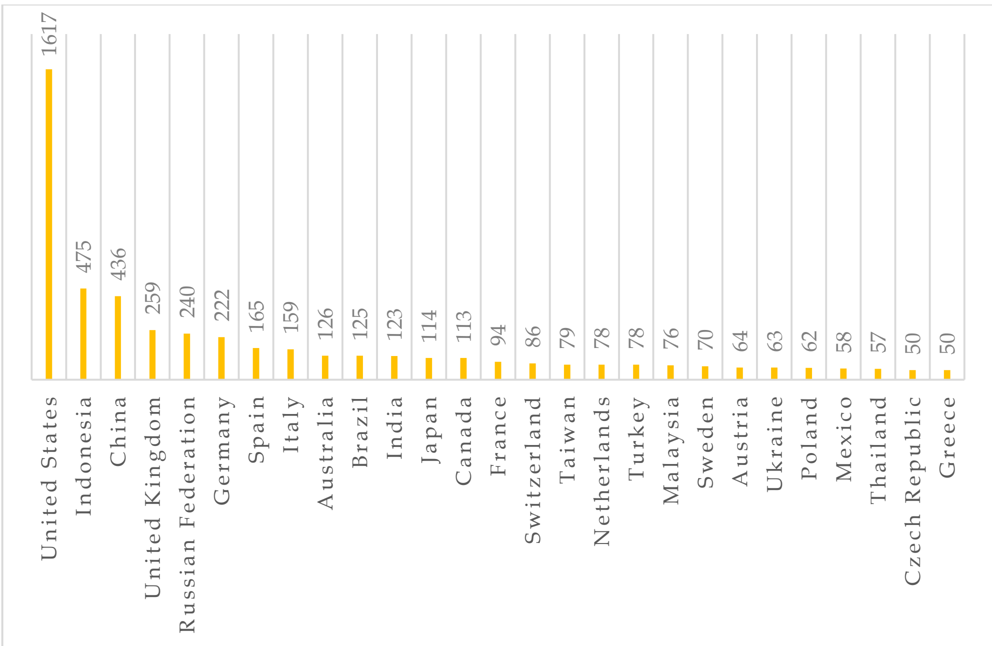


Figure 6

Top Countries in TiP Publications



Based on Figures 5 and **6,** in line with the most used language, the United States (1,617) is the most productive country for TiP publications from 1993 to 2022.

Trend Mapping Visualisation of TiP in Educational Fields During 1993 to 2022

The most occurrence keywords are analyzed before mapping out the occurances keywords of TiP publications during 1993-2022, as shown in Table 1. It can be seen that the highest total link strength (3,420) and the most frequently occurring keywords (441) are "Students."

Table 1

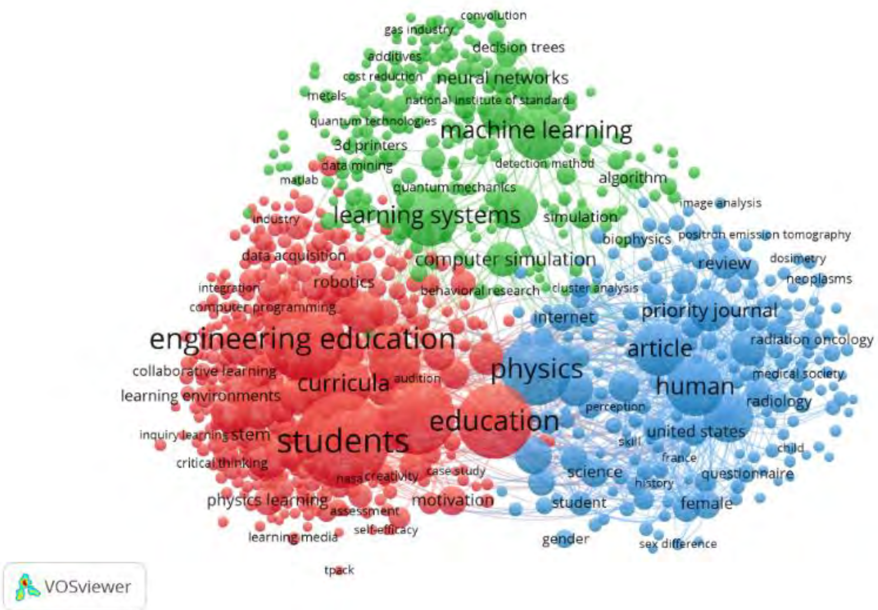
Top 20 Most Occurring Keyword in TiP Publications

Keyword	Occurences	Total Link Strength	Keyword	Occurences	Total Link Strength
Students	441	3,420	Curricula	149	1,258
Education	276	2,713	Machine learning	155	1,131
Teaching	279	2,511	e-learning	129	1,117
Engineering education	322	2,346	Medical learning	64	1,077
Human	166	2,338	STEM (Science, Technology, Engineering and Mathematics)	98	811
Article	142	2,076	Artificial intelligence (AI)	94	763
Physics	242	2,067	Virtual reality (VR)	89	743
Humans	125	1,875	Education computing (EC)	81	695
Learning systems	170	1,405	Curriculum	47	687
Priority journal	84	1,345	Educational technology	59	668

The metadata keywords are mapped to identify the TiP publication's recommendation in using techonology-based learning. To find a recommendation of the research based on the mapping results, look at the relationships between smaller or fewer keywords (Al-Husaeni & Nandiyanto, 2022; Escher, 2020; Nandiyanto et al., 2022). As in Figure 8 are all linked keywords.

Figure 7

Keyword Mapping Visualisation of TiP Publications during Three Decades



Hence, to find the novelties for future research of TiP publications in educational fields, the keywords are detailed to the fewest and most significant links, as in Figures 7 and 8 The mapping visualization of the metadata that presumably looks at the relationships between minor or fewer keywords to identify a novelty of the research based on the mapping results.

Figure 8

The Most Linked Keyword

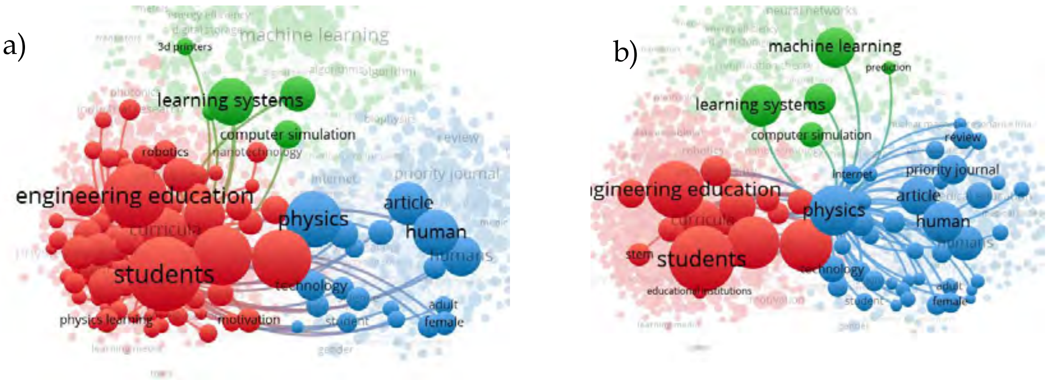
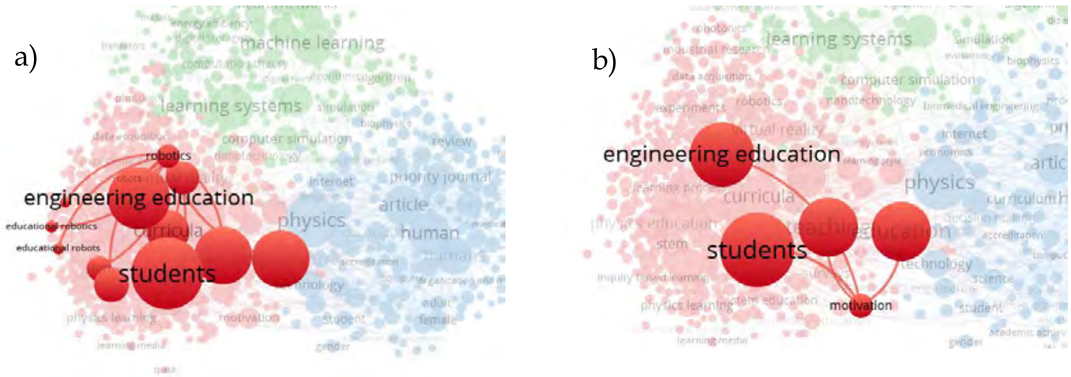


Figure 9

The Least Linked Keyword



Sponsorship Funding, Authors and Their Affiliations

Table 2 shows the lists of top sponsorship funding, affiliation, and authors of TiP in educational fields from 1993 to 2022 as references for further researchers to conduct, collaborate or elaborate research. The relationships between authors can be analyzed using Vosviewer, as in Figure 11.

Table 2

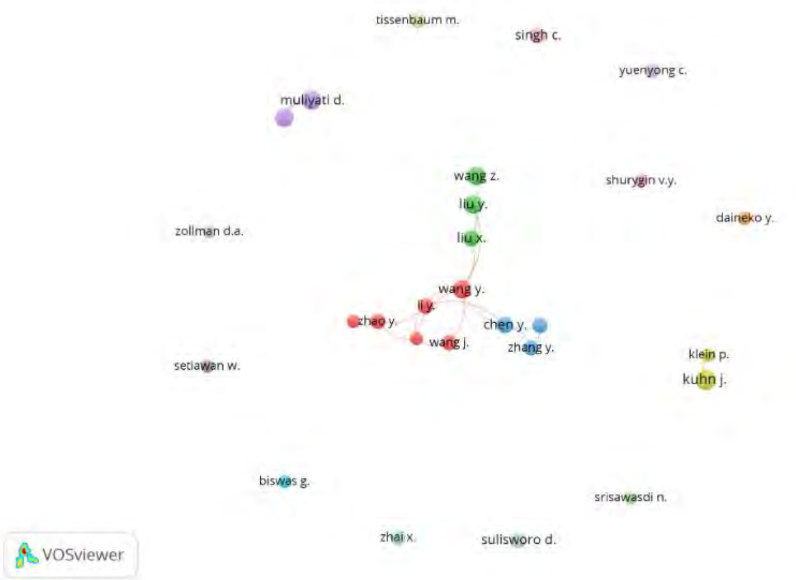
Top Sponsorship Funding, Affiliation and Authors in TiP Publications

Sponsorship Funding	Total	Affiliation	Total	Authors	Total
National Science Foundation	225	University of Indonesia	56	Bakri, F.	21
National Natural Science Foundation of China	94	Jakarta State University	54	Muliyati, D.	16
U.S. Department of Energy	55	State University of Padang	47	Romaniuk, R.S.	14
Horizon 2020 Framework Programme	34	Purdue University	44	Yuenyong, C.	14
European Commission	24	Yogyakarta State University	44	Kuhn, J.	12
Japan Society for the Promotion of Science	23	Stanford University	39	Wibowo, F.C.	12
Bundesministerium für Bildung und Forschung	19	Massachusetts Institute of Technology	38	Daineko, Y.	11

Sponsorship Funding	Total	Affiliation	Total	Authors	Total
National Institutes of Health	19	Texas University	31	Sprawls, P.	11
Office of Science	19	Arizona State University	28	Sulisworo, D.	11
Engineering and Physical Sciences Research Council	18	University of Michigan, Ann Arbor	27	Jumadi	10

Figure 10

The Mapping Visualisation of Authors in TiP Publication



Top Subject Areas and Sources of TiP

The top subject areas and source titles are being analysed to open the possible subject areas that can be developed in TiP and subject areas that still need to be correlated with TiP so that they can develop. Table 3 shows the top subject areas and source titles of TiP publications in educational fields from 1993 to 2022.

Table 3

The Top Subject Area and Source Title to TiP Publications

Subject Area	Total	Source Title	Total
Engineering	1,921	Journal Of Physics Conference Series	601
Physics and Astronomy	1,708	ASEE Annual Conference and Exposition Conference Proceedings	204
Social Sciences	1,529	Aip Conference Proceedings	150
Computer Science	1,526	Proceedings Of SPIE The International Society for Optical Engineering	150
Mathematics	519	Medical Physics	80
Materials Science	431	ASEE Annual Conference Proceedings	75
Medicine	355	Physics Education	59
Energy	278	Proceedings Frontiers in Education Conference	53
Earth and Planetary Sciences	208	Ceur Workshop Proceedings	51

Distribution of Top Cited Publication TiP During 1993 to 2022

Table 4 shows the distribution of publications on TiP publication during 1993-2022. ACPP is known as Average Citation Per Paper, the highest rank of the paper distribution noted by the *.

Table 4

Paper Distribution of TiP Publications 1993-2022

Year	Paper	Cited	ACPP	ACPPY	Citable Years	Year	Paper	Cited	ACPP	ACPPY	Citable Years
1993	19	220	11.58	0.39	30	2009	175	1,641	9.38	0.67	14
1994	18	52	2.89	0.10	29	2010	233	2,359	10.12	0.78	13
1995	50	68	1.36	0.05	28	2011	200	2,509	12.55	1.05	12
1996	32	351	10.97	0.41	27	2012	189	1,181	6.25	0.57	11
1997	38	282	7.42	0.29	26	2013	234	851	3.64	0.36	10
1998	31	24	0.77	0.03	25	2014	198	6,602*	33.34*	3.70*	9
1999	36	323	8.97	0.37	24	2015	231	1,462	6.33	0.79	8
2000	40	282	7.05	0.31	23	2016	237	2,252	9.50	1.36	7
2001	66	1,147	17.38	0.79	22	2017	296	1,782	6.02	1.00	6
2002	63	337	5.35	0.25	21	2018	345	3,289	9.53	1.91	5
2003	78	440	5.64	0.28	20	2019	567	2,250	3.97	0.99	4
2004	64	978	15.28	0.80	19	2020	602	1,964	3.26	1.09	3
2005	115	1,874	16.30	0.91	18	2021	664*	1,281	1.93	0.96	2
2006	110	985	8.95	0.53	17	2022	581	74	0.13	0.13	1
Year	Paper	Cited	ACPP	ACPPY							
Total	5,512	36,860	235.86	20.86	-						

Publication Review and State of The Art of TiP 1993-2022

Table 5 reviews previous research filtered by the highest citation of TiP publication from 1993 to 2022. The chosen publication is identified as publications related to educational fields with specific titles, abstracts, or other keywords.

Table 5

Publication Review of TiP Publication in Educational Fields During 1993-2022

Author(s)	Citation	SJR-CiteScore (2021)-Percentile to Education (2020)	Findings	Recommendations
(Deslauriers et al., 2011)	715	14.589 (Q1)-57.8-(98th)	In different instructional approaches, there is an increase in student attendance, high engagement using research-based instruction.	For subsequent research, it can use more diverse research subjects so that results tend to be generalized in certain schools
(Potkonjak et al., 2016)	442	3.68 (Q1)-19.8-(99th)	Advances in computer graphics, virtual reality, and cyber technology can accelerate the use of virtual laboratory-based system applications so as to reduce the real needs of laboratories.	It is recommended that the use of virtual lab simulators be applied in deep learning with real original equipment.
(Dori & Belcher, 2009)	332	2.52 (Q1)-9.8-(98th)	The Active Learning Project uses Technology (TEAL) at the Massachusetts Institute of Technology (MIT) to analyze students' cognitive and affective outcomes.	Based on the assessment results, subsequent research is recommended adding active learning, technology-based components from the TEAL course to the basic undergraduate mechanics course as well.

Author(s)	Citation	SJR-CiteScore (2021)-Percentile to Education (2020)	Findings	Recommendations
(Hwang et al., 2009)	284	3.68 (Q1)-19.8-(99th)	The use of Context-aware ubiquitous learning (u-learning) as an innovative approach that integrates wireless, mobile, and context-awareness (u-computing) technologies to detect real-world learner situations and provide appropriate adaptive support or guidance for students.	It is recommended that "graphic illustration" can make the u-computing PDA interface more attractive with the u-computing system having to record many learning patterns based on the experience of each learner.
(Akçayir et al., 2016)	281	2.17 (Q1)-1.2-(24th to neuroscience)	AR technology improves students' laboratory skills and helps them build a positive attitude towards physics labs	It is recommended that the use of virtual lab simulators be applied in deep learning with real original equipment.

Discussion

Based on Figure 2, research number on TiP educational fields from 1993 to 2022 are increasing every year. In early 2023, 43 documents had been published. It shows that interest in TiP continues to increase (Azlan et al., 2020; Fahmi et al., 2022; Vandenberghe et al., 2020). This is because TiP is considered capable of becoming a learning medium that covers many aspects of physics learning that contains many abstract and complex materials (Astuti et al., 2019; Hahn & Klein, 2022; Rahardja et al., 2019; Sudarsana et al., 2019; Syakroni et al., 2019). Especially in 21st-century learning, it is an alternative to enhance the pupil's motivation to study physics, which is considered difficult by many pupils (Abdurrahman et al., 2019; Novitra et al., 2021; Rizaldi et al. al., 2021; Sari et al., 2022). English is the most widely used language (5,523), followed by Portuguese (65), Spanish (47), Chinese (42), and Russian (38). English is a universal global language (Davidson & Liu, 2020; Sari & Aminatun, 2021; Sofyan, 2021). As a result, the circulation of publications will have to be more significant and much more extensively utilized or read as a reference point among many individuals (Hussain, 2019; Ramírez-Castañeda, 2020).

TiP implementation and development have been actively undertaken in the United States at every institutional level during these three decades (Borda et al., 2020; Rapanta et al., 2020; Wang et al., 2022; Yik et al., 2022). The US exhibits the greatest link strength (268) and number of citations (26,679). There are 7 clusters, namely Cluster 1 (15 items) including Australia, Belgium, India, Indonesia, Japan, Malaysia and New Zealand; Cluster 2 (15 items) including Cyprus, Czech Republic, Germany, Greece, Iran and Israel; Cluster 3 (8 items) consists of Argentina, Chile, Mexico, Morocco, Portugal, Spain, Sweden, etc. Cluster 4, with yellow node (5 items), consists of China, Hongkong, Saudi Arabia, United Kingdom, and United States. Cluster 5 with lilac node (5 items) consists of Austria, Finlandia, France, Serbia, and Switzerland. Cluster 6 with turquoise nodes (5 items) consists of Canada, Denmark, Ireland, Norway, and Slovenia. Cluster 7 tangerine color node (3 items) consists of Hungary, Italy, and Romania.

Based on Table 1, 'Students' is the main keyword of TiP publications. At the same time, the second place is 'Education' with total link strength of 2,713 and occurrences 276. Followed by Teaching, Engineering Education, Humans, Articles, Physics, Humans, Learning Systems, and others. Based on this pattern, it can be found that the trends of TiP publications during the past three decades are: 1) related to students; 2) implementation of education and teaching-human; 3) primarily used in engineering education or else medical education; 4) Output research by article key words; 5) learning systems; 6) Integrating to curricula; 7) Emerging as STEM education could be A.I., V.R., and so on; 8) Educational technology.

Figure 7 depicts term co-occurrences throughout all TiP articles during the last three decades (1993-2022). The mapping visualization shows that there are three main clusters. Cluster 1, coloured by red node (368 items), consists of abstracting, academic performance, applied physics, Arduino, augmented reality (A.R.), e-learning, education, educational technology, STEM, physics laboratory, physics learning, physics phenomena, mobile learning, V.R., technology enhance learning and so on. Cluster 2, coloured by a green node (241 items), consists of A.I., atomic physics, biotechnology, deep learning, emerging technologies, energy utilization, machine learning, molecular physics, quantum physics, etc. Cluster 3, coloured by blue node (204 items), consists of academic achievement, biophysics, chemistry, curriculum, C.P., education and training, education, medical, engineering, learning environment, online system, physics, problem-based learning, publication, radiology, science, students, university, and so on. Again, discuss importance/significance. Why should these findings be of interest to us?

Figure 8 is the most linked keywords in TiP publication, whereas Figure 9 is the opposite. Suppose the research study wants to investigate TiP publication on top trends. In that case, there is still any chance to explore because the top trends still have a wide range and various fields of terms such as Figure 9a) 'Students' keyword remains available to discover perform an advancement or modify in educational environments, engineering education, physics or else. However, TiP may help and improve education in a variety of ways. 'Robotics,' may serve as a possible alternative learning media future research field, particularly to investigate TiP prior to merging with robotics (Auyelbek et al., 2022). How TiP can improve motivation in engineering education or for larger classes of all stages of education (Godwin & Kirn, 2020; Hadgraft & Kolmos, 2020; Hernández-de-Menéndez et al., 2019; Qadir & Al-Fuqaha, 2020).

Based on Table 2, the National Science Foundation is in first place as sponsor at 225 publications, followed by the National Natural Science Foundation of China with 94. In third place, followed by the U.S. Department of Energy, Horizon 2020 Framework Programme. Sponsorship activities for most of the world's largest audiences are critical. Most of them make investments to carry out sponsorship activities to achieve the desired goals or results. Sponsorship funding usually chooses many goals, one of which is to help improve the reputation of article publications. Top sponsorship funding mapping project as a consideration of publication reputation (Phuong et al., 2022).

Based on Figure 10, Bakri, F. is the leading author by total link strength, followed by Muliyati, D. with the same total link strength. However, the most cited author is Kuhn, J., with 11 documents and total link strength of 4. Many authors are not linked to each other. It shows the author's loyalty to TiP (Dangaiso et al., 2022). Furthermore, the Indonesian University of Education occupies the first top affiliation place, with 56 publications, followed by Jakarta State University, with 54 full publications. Subsequent positions are occupied by the State University of Padang, Purdue University, Yogyakarta State University, Stanford University, Massachusetts Institute of Technology, Texas University, Arizona State University, and University of Michigan, Ann Arbor. The form of cooperation between colleagues and TiP publications can be seen through mapping data. Various top universities are affiliated with TiP publications that demonstrate the quality of good cooperation in education (Stoner et al., 2019).

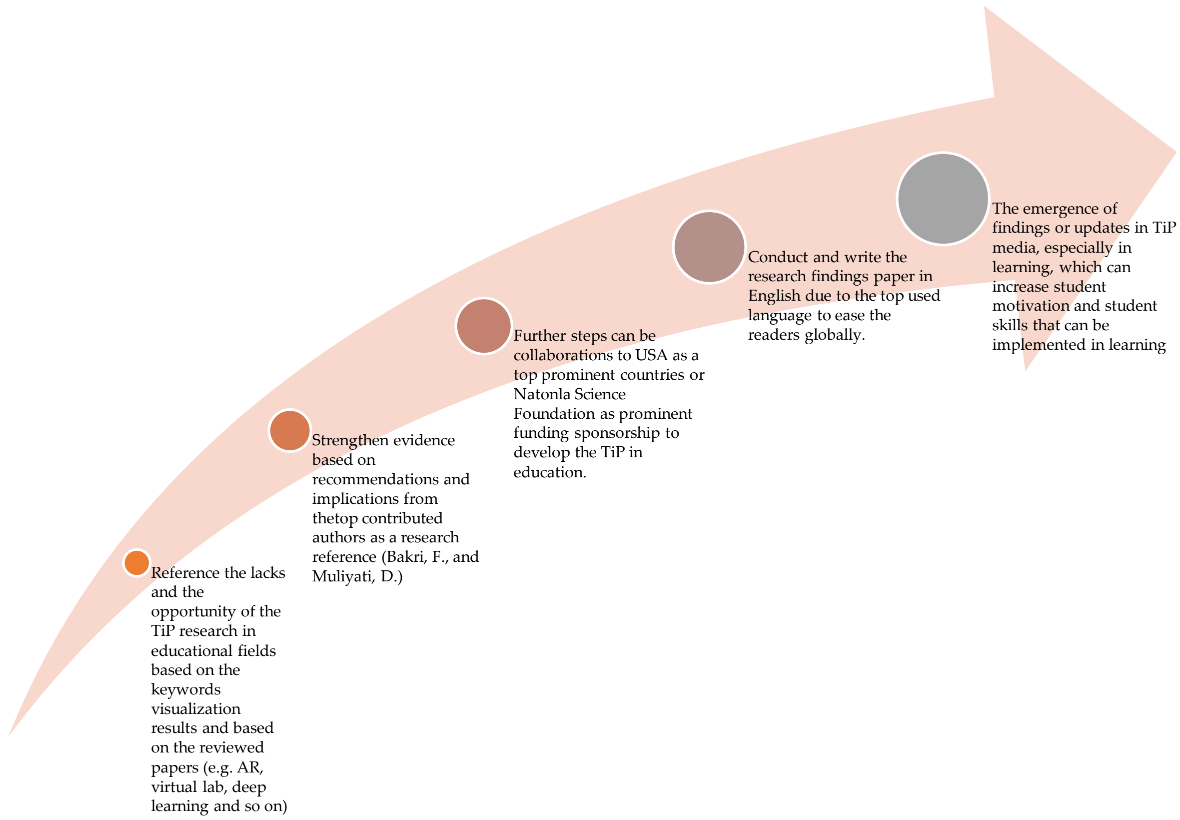
Based on Table 3, the most common subject areas are Engineering, totaling 1,921. Physics and Astronomy are second, followed by Social Sciences, Computer Science, Mathematics, Materials Science, Medicine, and Energy. The top source title, namely the Journal of Physics Conference Series as many as 601 then followed by ASEE Annual Conference and Exposition Conference Proceedings, AIP Conference Proceedings, Proceedings of SPIE The International Society for Optical Engineering, Medical Physics, ASEE Annual Conference Proceedings, Physics Education, Proceedings Frontiers in Education Conference, Lecture Notes in Computer Science Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics, Ceur Workshop Proceedings. The mapping of the subject area and source title was carried out to analyze the strategic location of TiP publications' novelty in the education field (Olusola et al., 2022).

Based on Table 4, the year with the most papers is 2021 (664). In comparison, the most cited (6,602) papers are in the year 2014, followed by ghe highest ACPP (33.34) and ACPPY (3.70). İn contrast, 1994 is the year with the fewest papers (18), but 2007 and 2008 are years with no publications at all, and hence there is no ACPP and ACPPY. The total number of papers through the three decades is 5,512, with 36,860 citations and 235.86 ACPP, 20.86 ACPPY. Based on Table 5, the results of the study and analysis of the publication review of TiP during 1993-2022 is the use of learning media result from, which can identify students' cognitive and affective results as innovations in physics learning. Adaptive guidance is also needed for students to recognise and build attitudes toward physics. The involvement of technology was instrumental in familiarising students with detecting real-world learning situations with a range of support over three decades. Hence, the emergence of technology plays an essential role in research from publications cited (Chang & Hwang, 2019; Jabbour et al., 2020).

Based on the research findings the research route for TiP in educational fields are emerged technology such as engineering education based on the main keyword to adapt. Otherwise, the further term is linked TiP education to the integrating of robotics to enhance the students' incitement of physics learning (Godwin & Kirn, 2020; Hadgraft & Kolmos, 2020). The research of the TiP in educational fields to future research are likely in Figure 11.

Figure 9

Rsearch Route to TiP Education for Future Research



Based on the Figure 10, further research are recommended to conduct the research of TiP in English based on the most used language to ease reader all around the world. This is line with the finding of the most prominent country to developed TiP publication being the United States with the most linked strength. Otherwise, further researchers can refer to Bakri, F. and Muliyati, D. of the TiP in fields education especially to AR technology, due to finding of the top prominent authors in English language. Based on the Table 5 likely it is recommended that the use of virtual lab simulators be applied in deep learning with real original equipment and Akçayir et al., (2016) recommended that the use of virtual lab simulators be applied in deep learning with real original equipment. However, the reviewed paper are listed in the top quartile ranked and filtered by the top cited paper on the Scopus, it is implying that a publication with the mentioned achievement is published with unquestionable reliability since the publisher has a high reputation. Hence, the future study can be confident in the references that have been reviewed, and use the findings (e.g. further development of AR, implement of virtual lab, integrating of deep learning, and so on) as opportunities for TiP in the education sector.

Conclusion and Implication

In summary, the fundamental findings derived from the extensive bibliometric analysis of Technology in Pedagogy (TiP) publications in educational fields over the past three decades (1993-2022) through the Scopus database and VOSviewer application offer crucial insights and lay the groundwork for future research endeavors. The identified trends, including the consistent rise in TiP publications, the prevalence of C.P. as the most published document type, and the dominance of English in these publications, underscore the enduring global significance of TiP in education. Moreover, the recognition of key contributors, such as the National Science Foundation and prominent authors like Bakri, F., along with their affiliations, sheds light on the collaborative nature of TiP research. The subject-wise distribution highlights the prominence of engineering in TiP publications, signaling its central role in shaping educational practices.

Based on these findings, several recommendations for future research emerge. First and foremost, researchers are encouraged to explore emerging trends identified in this study, such as the integration of robotics and the application of AR technology. These represent promising avenues for advancing TiP's impact on educational practices and student outcomes. Additionally, the identified temporal patterns and the high reliability of TiP publications suggest the need for continued collaboration and exploration of niche topics. Collaborative efforts across institutions and countries can further enrich the discourse, while focusing on specific themes, like deep learning with real equipment using virtual lab simulators, can contribute to the continued evolution of TiP in education.

In conclusion, these fundamental findings and recommendations provide a comprehensive foundation for researchers, educators, and policymakers to deepen their understanding of TiP in educational fields, guiding future endeavors towards innovative and impactful contributions to the intersection of technology and pedagogy.

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