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Comparison of Top 100 Cited Research on Machine Learning and Deep Learning in The Last Twenty Years

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ABSTRACT

Objective: *The aim is to compare the top 100 research related to machine learning (ML) and deep learning (DL) during 2002-2021 using bibliometric analysis.* ***Method:*** *The data were obtained from Scopus. The data taken in this research were selected from 100 articles with the highest citation in the range from 2002 to 2021. Bibliometric analysis is used in this research. Data from Scopus is exported in the form of .csv form which is processed using Ms. Excel and form of .ris which is processed using VOSviewer.* ***Results:*** *The results showed that the trend of ML and DL increased every year. The most widely published document types in ML are articles, while DL is in the form of conference papers. The highest year-wise distribution of publishing ML and DL occurred in 2017. ML advantages are in terms of requires less data and take less time to train, while the DL advantages in terms of higher accuracy than ML, available to tuned in various different ways.* ***Novelty:*** *This research being able to provide an overview for future researchers regarding the trend of ML and DL topics so that the resulting paper can provide various benefits for the coming year. In addition, it can provide broader knowledge about ML and DL itself. Further research can be carried out more intensively using data based on the Web of Science, in addition to the Scopus database.*

INTRODUCTION

The development of education in the world year by year is always changing. Learning in higher education has experienced a steady increase in the last decade (NCES, 2020; Zhang et al., 2021). In the education, we will find its own challenges, both external and deep physical problems (Conde et al., 2020; Hung et al., 2014; Rastegarmoghadam & Ziarati, 2017). Identification in each element is a very important factor and it becomes one of the main challenges in education (Zuo et al., 2022). By knowing how important education is, the US government provides grants for the development of a better education process (Sabirova et al., 2020).

The education system is not only problem-oriented but also project-oriented. In general, education is less effective because the available resources are limited, the skills of natural teachers in designing learning models are also lacking (Alberts, 2022; Liu, 2020; Licardo & Leite, 2022). However, with the times, an alternative method has been found, namely using machine learning (ML) with phase transitions until the system uses sequence parameters that cannot be doubted (Alghamdi, 2020; El Guabassi et al., 2021). On the other hand, there is also deep learning (DL) which can create patterns for decision-making purposes during the education process (Shorten & Khoshgoftaar, 2019; Wang et al., 2022).

Good learning is learning that can make a positive contribution to students, teachers and the education system. Machine learning (ML) based techniques are an effective way to either study or predict physical properties (Bottou et al., 2018; Chen & Tong, 2019; Ouatik et al., 2021; Zahour et al., 2020). Deep learning (DL) based techniques are a very effective way to solve problems with a high level of difficulty (Lakin & Wai, 2022; Levine et al., 2018; Zhao et al., 2019). Based on research conducted by Belmonte et al. (2020) there is still limited access to find out which learning topics have the greatest impact.

The limited access out there to find out which articles have a big impact on education can be minimized using bibliometric analysis. Several papers published in journals can show the growth of literature in scientific disciplines so that this can be an in-depth study of the discipline as a whole (Bharvi et al., 2003; Mukherjee, 2009). The most appropriate analysis to compare learning systems is to use bibliometrics that have been tried at various country levels (Das, 2013; Garg & Singh, 2022; Kevin et al., 2009; Patil & Lihitkar, 2018). Previous research by Pande & Mulay (2020) stated that bibliometrics in machine learning has not been discussed more broadly. Strengthened by previous research by Li et al. (2020) has suggested that bibliometric research needs to be done again to find out the development of research on deep learning every year.

With the explanation of the limitations above, this research was conducted with the aim is to compare the top 100 research related to machine learning and deep learning in the last twenty years using bibliometric analysis. The research questions (RQ) that arise include :

RQ1 : What is the trend research of machine learning and deep learning articles from 2002 to 2021?
RQ2 : How is the document types of publishing machine learning and deep learning articles from 2002 to 2021?
RQ3 : How is the year-wise distribution of publishing machine learning and deep learning articles from 2002 to 2021?
RQ4 : What is the most used keyword of the top 100 cited machine learning and deep learning publications in the last 20 years?
RQ5 : Which country and author had the highest publication on machine learning and deep learning in the last 20 years?
RQ6 : How do the comparison of machine learning and deep learning in terms of similarities and differences; advantages and disadvantages?

RESEARCH METHOD

This study is quantitative research using literature review from Scopus database. The data collection process was carried out on March 6, 2022. The data taken in this study were selected from 100 articles with the highest citation in the range from 2002 to 2021. Bibliometric analysis is used in this study because it focuses on citations from previous research documents (Chhapola et al., 2018; McNicholas et al., 2022). Bibliometrics consists of describing the relationship between documents, authors, disciplines, and domains (Small, 1999).

Data from Scopus is exported in the form of .csv form which is processed using Ms. Excel (Hashim et al., 2018) and form of .ris which is processed using VOSviewer in order to get bibliometrics map conduct frequency of co-occurrence and collaboration between authors across countries (Mustapha et al., 20210. VOSviewer has proven effective for analyzing recent studies with the Scopus index (Parmar et al., 2020). With publications looking for trends with bibliometric analysis, this can describe the movement of the scientific world to date (Calabuig-Moreno et al., 2020; Shubina & Plakhotnik, 2021). Flowchart from this reseach can be seen in Figure 1 and Figure 2.

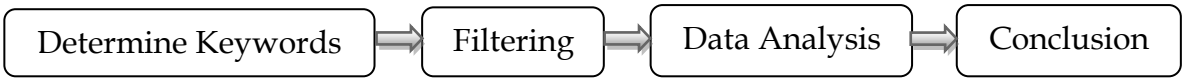


Figure 1. Flowchart for the research

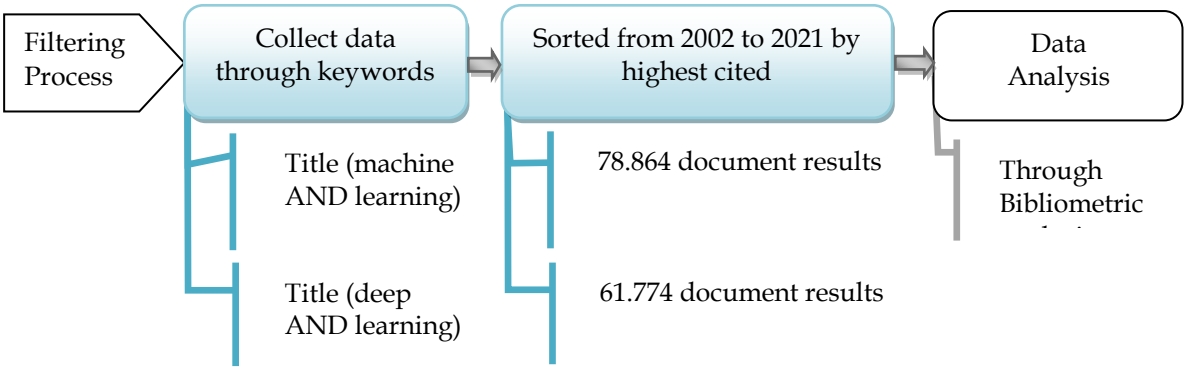


Figure 2. Flowchart for the keyword filtering

RESULTS AND DISCUSSION

Publication Trend

The results of the trend of article publications can be seen in Figure 3a and Figure 3b. Overall the two graphs appear to be rising consistently, this shows that machine learning (ML) and deep learning (DL) are topics of interest for ongoing research. These results are reinforced by previous studies by Sobral (2021) and Zhang et al. (2021) that the rating of enthusiasts for publications regarding ML and DL continues to increase. Thus, it can be predicted that the trend of ML and DL publications will increase in the next years.

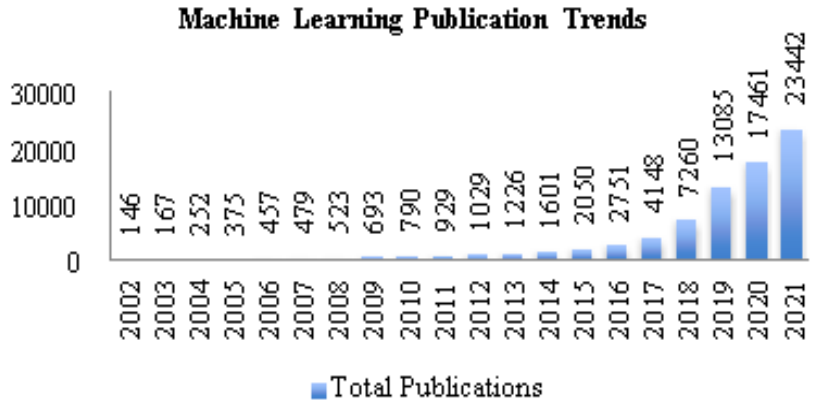


Figure 3a. Machine learning publication trends.

Publications with the topic of ML from 2002 to 2021 have increased every year. The highest increase in the number of publications occurred in 2021 as many as 5981 publications. The lowest increase in the number of publications occurred in 2003 with a difference of 21 publications compared to 2002.

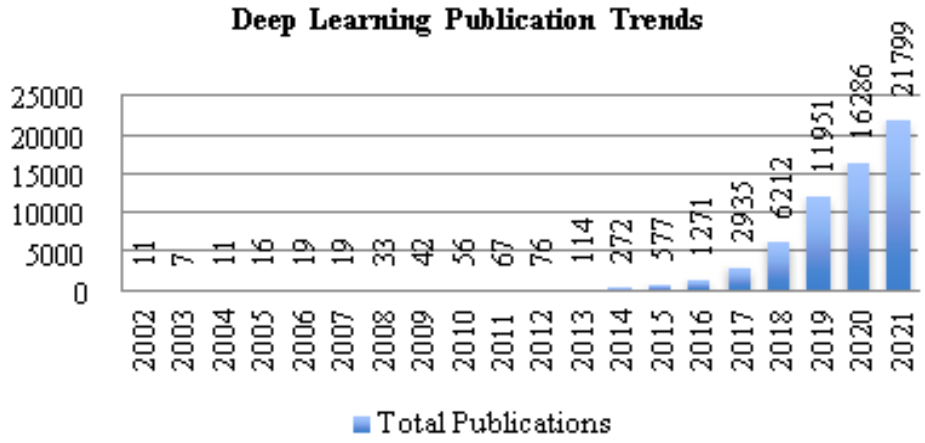


Figure 3b. Deep learning publication trends

Publications with the topic of DL from 2004 to 2021 have increased every year. There was a decline publications in 2003 as many as 4 publications. However, the decrease did not have a significant impact because in the following years the topic of DL is increasing every years. The highest increase in the number of publications occurred in 2019 as many as 5739 publications.

Document Type

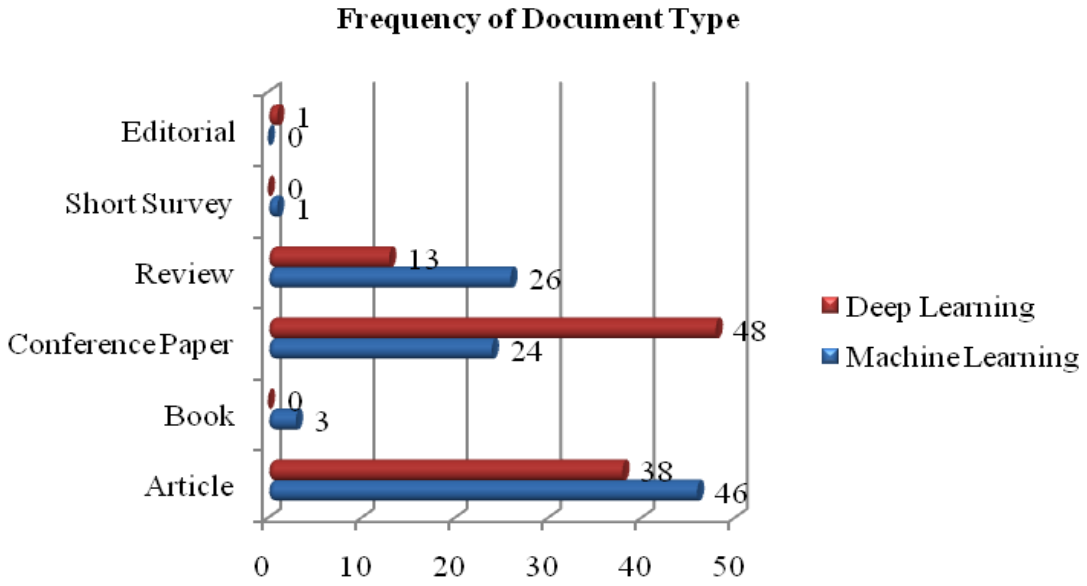


Figure 4. Frequency of Document Type

Based on Figure 4, the comparison of publications between ML and DL according to the top 100 document types of the highest citations. In ML it has a short survey document type while DL does not and vice versa DL has an editorial document type while ML does not. For ML, the highest document type is articles (n=46), while for DL the highest document type is conference paper (n=48).

Table 1. Document type from the top 100 publications with the highest citations of machine learning (ML) and deep learning (DL).

Doc Type	Cited		Mean		Median		SD	
	ML	DL	ML	DL	ML	DL	ML	DL
Article	80370*	70668	1747	1860	846	1060	4510*	2282
Book	6139	-	2046*	-	697	-	19	-
Conferen	48042	134242	2002	2797	895*	1100*	2122	9068*

Doc Type	Cited		Mean		Median		SD	
	ML	DL	ML	DL	ML	DL	ML	DL
ce Paper		*						
Review	28235	57405	1086	4416*	826	1173	967	8883
Short Survey	523	-	523	-	523	-	-	-
Editorial	-	937	-	937	-	937		-
Total	163309	262315	7404	9073	3787	3333	7618	20233

*The Highest Number SD = Standard Deviation

Based on Table 1, the most cited publications on ML topics were in the form of articles (n=80,370), while the most cited DL publications were in the form of conference papers (n=134,242). So that the standard deviation of ML and DL is quite high, namely 4,510 in the form of articles and 9,068 in the form of conference papers. Thus, it can be concluded that researchers tend to be interested in writing ML topics in the form of articles, while DL in the form of conference papers.

The Distribution of Year-Wise Top 100 Highest Cited Publication

Table 2. The distribution of year-wise from top 100 highest cited publication on machine learning.

Machine Learning					
Year	**Cited**	**Paper**	**ACPP**	**ACPPY**	**Citable Years**
2002	8509	3	2836.3	141.8	20
2003	4186	4	1046.5	55.1	19
2004	5142	3	1714	95.2	18
2005	1844	2	922	54.2	17
2006	11463	4	2865.8	179.1	16
2007	3156	3	1052	70.1	15
2008	2923	3	974.3	69.6	14
2009	3887	4	971.8	74.8	13
2010	8524	8	1065.5	88.8	12
2011	31896*	2	15948*	1449.8	11
2012	14328	10	1432.8	143.2	10
2013	2586	3	862	95.8	9
2014	9182	5	1836.4	229.6	8
2015	16682	11	1516.5	216.6	7
2016	22177	11	2016.1	336*	6
2017	9665	13*	743.4	148.7	5
2018	4040	6	673.3	168.3	4
2019	4185	5	837	279	3
2020	0	0	-	-	2
2021	0	0	-	-	1
Total	164375	100	21335	615	

*ACPP= Average Citation Per Paper , ACPPY= Average Citation Per Paper Per Year, *The Highest Number*

Table 3. The distribution of year-wise from top 100 highest cited publication on deep learning.

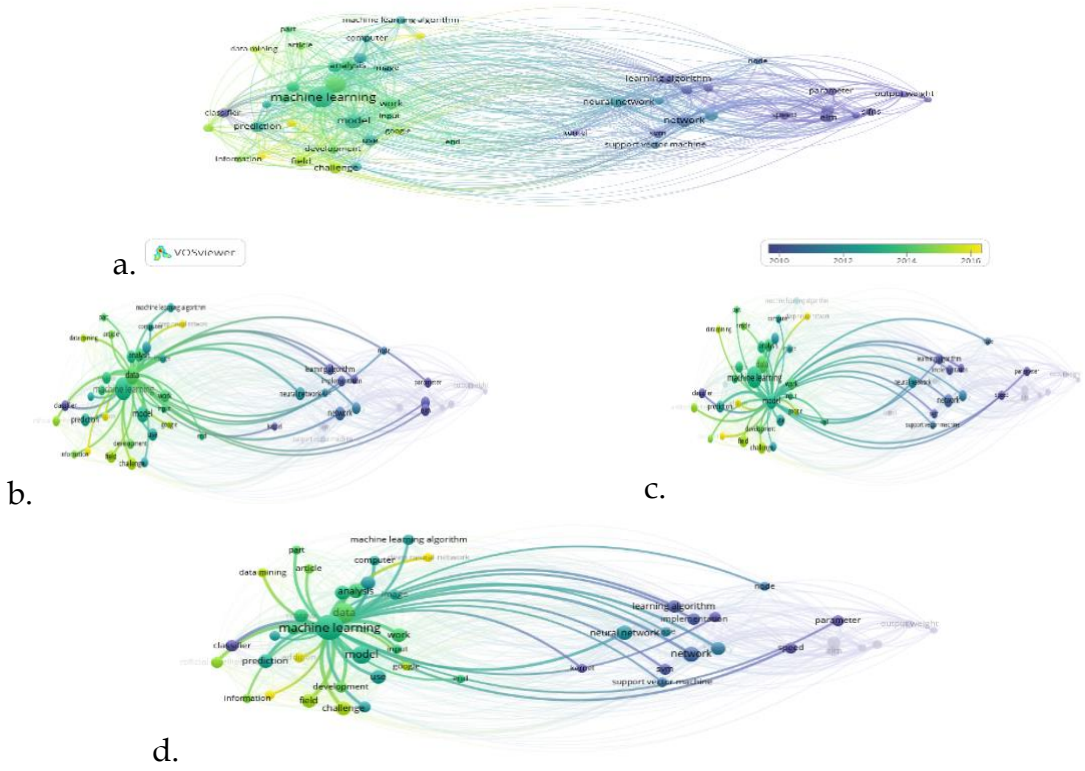
Deep Learning					
Year	**Cited**	**Paper**	**ACPP**	**ACPPY**	**Citable Years**
2002	0	0	-	0	20
2003	0	0	-	0	19
2004	0	0	-	0	18
2005	0	0	-	0	17
2006	10521	1	10521*	657.6	16
2007	0	0	-	0	15
2008	3343	1	3343	238.8	14
2009	8053	3	2684.3	206.5	13
2010	6597	3	2199	183.2	12
2011	2993	2	1496.5	136	11
2012	833	1	833	83.3	10
2013	4740	4	1185	131.7	9
2014	10560	7	1508.6	188.6	8
2015	66803	16	4175.2	596.5	7
2016	91036*	20	4551.8	758.6*	6
2017	35308	23*	1535.1	307	5
2018	9440	10	944	236	4
2019	12276	8	1534.5	511.5	3
2020	749	1	749	374.5	2
2021	0	0	-	0	1
Total	263252	100	19774	679	

*ACPP= Average Citation Per Paper , ACPPY= Average Citation Per Paper Per Year, *The Highest Number*

From the top 100 publications on machine learning (ML) and deep learning (DL), it can be seen about the highest number of paper publications per year, the year with the highest citations, the average citations per paper and the average citations per paper per year. The highest unit for publication of papers regarding ML and DL occurred in 2017 namely ML as many as 13, while DL as many as 23. The highest citations regarding ML occurred in 2011 as many as 31,896; while DL in 2016 was 91,036. For the total citations per year the topic of ML was higher than DL with a difference of 98,877.

Keyword Visualization

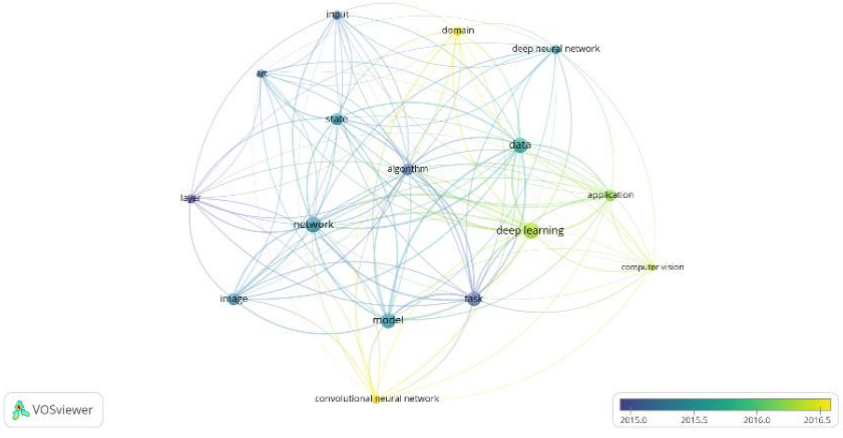
Keywords can represent important points in discussing the content of a paper. With the overlay, it can display the use of keywords based on the year of publication of the paper (Limaymanta et al., 2021). The overlay results of machine learning (ML) are shown in Figures 5 and deep learning (DL) topics are shown in Figures 6.



a. b. c. d.

Figure 5. The overlay visualization of machine learning keywords a.) all machine learning, b.) data, c.) model d.) Focused machine learning

In the search for machine learning (ML) topic keywords in the 2002-2021 range, VOSviewer is used. The file format used is .ris with binary counting generated from the 2505 terms, 83 meet the threshold. Thus generated 3 keywords that are dominantly used by researchers, namely machine learning, data and models. The three keywords are related to the world of education, one of which is learning algorithms, computers, information, etc. With such results, researchers who want to use these keywords still have a good chance for the benefits of their paper. Because the topic of ML has a very wide range.



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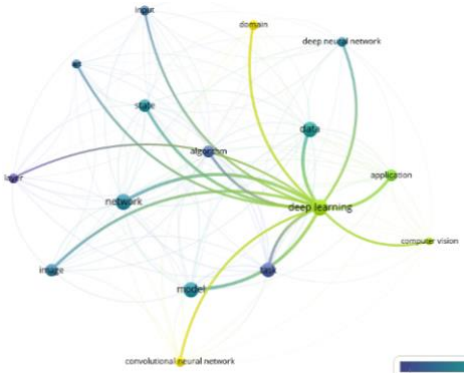

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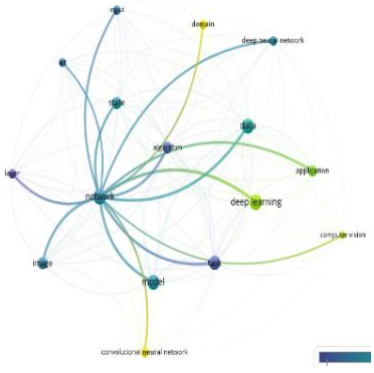

Figure 6. The overlay visualization of deep learning keywords a.) all deep learning, b.) focused deep learning, c.) network.

In the search for deep learning (DL) topic keywords in the 2002-2021 range using VOSviewer. The file format used is .ris with binary counting generated from the 2600 terms, 26 meet the threshold. Thus, 2 keywords that are dominantly used by researchers are generated, namely machine learning, and network. The two keywords are related to the world of education, one of which is algorithm, computer vision, art, etc. With such results, researchers who want to use these keywords still have a good chance for the benefits of their paper. Because the DL topic has a fairly broad range, although not as wide as the ML topic.

Top Authors Profile and Top Country

Table 4. Top 10 author with highest citation during last 20 years.

Machine Learning (ML)				**Deep Learning (DL)**			
Author	**TD**	**TC**	**Country**	**Author**	**TD**	**TC**	**Country**
Pedregosa, Fabian	32	37278	United States	He, Kaiming	72	166226	United States
Abadi, Martin	232	25317	United States	Lecun, Yann Le	201	96907	United States
Huang, Guangbin	210	40718	Singapore	Hinton, Geoffrey E.	236	231666*	Canada
Cho, Kyunghyun	150	26028	United States	Mnih, Volodymyr	25	14872	Canada
Sebastiani, Fabrizio	134	12394	Italy	Schmidhuber, Jurgen U.	312	79903	Switzerland
Bahdanau, Dzmitry	14	14688	Canada	Bengio, Yoshua	433*	197157	Canada
Zhou, Hongming	13	5983	Singapore	Paszke, Adam	5	5113	United States
Witten, Ian H.	278*	17810	New Zealand	Litjens, Geert J.S.	80	10559	Netherlands
Zhu, Qinyu	8	13091	Singapore	Vincent, Pascal	55	15966	United States
Bottou, Leon	87	46594*	United States	Chollet, Francois	5	4241	United States

*TD = total documents TC = Total Citation *The Highest Number*

Based on Table 4. Top 10 authors for ML and DL topics are dominated by researchers from the United States. Author with the highest citation for the ML topic is Pedregosa,

while the DL topic is He Kaiming. However, the highest total citations were occupied by Bottou from United States and Hinton from Canada. In the top author, the topic ML Witten from New Zealand has the highest total documents. And for the topic DL Bengio from Canada has the highest total documents.

To find the top author, not only through literature review but also through bibliometric testing in VOSviewer. Top author mapping can be analyzed with VOSviewer (Eck & Waltman, 2013; Eck & Waltman, 2017; Ali et al., 2021). Cluster division can show connections between authors. There are 4 clusters for machine learning top author. Clusters are generated from filtering a maximum of 25 authors per document and a minimum of 2 documents from an author, resulting in 13 authors classified into 4 clusters. Cluster with yellow color (n=2), cluster with green color (n=4), cluster with blue color (n=3) and cluster with red color (n=5). Huang, G-B is the main author for the ML topic because it has the highest citations and highest connections compared to other authors.

There are 4 clusters in for deep learning top author. Clusters are generated from filtering a maximum of 25 authors per document and a minimum of 2 documents from an author, then 12 authors are generated which are classified into 4 clusters. Cluster with yellow color (n=2), cluster with green color (n=4), cluster with blue color (n=2) and cluster with red color (n=4). Chen, y became the main author for the DL topic because it has the highest citations and highest connections compared to other authors. For top country described in Figure 7a and 7b.

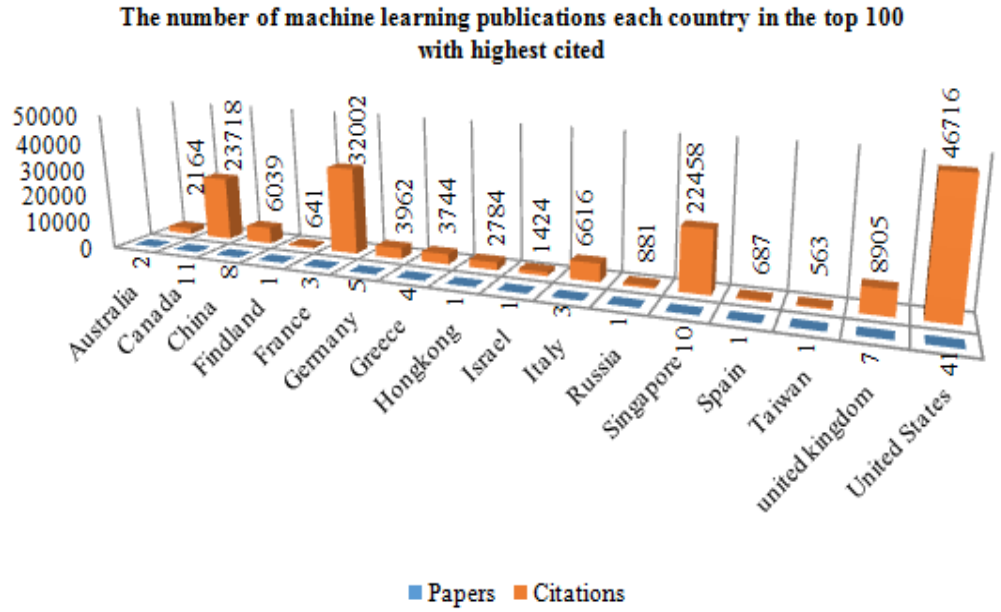

Figure 7a. The number of machine learning publications each country in the top 100 with highest cited

On the topic of machine learning (ML) the countries that are included in the top 100 highest citations in the 2002-2021 range are 16 countries. The country with the most paper publications and the highest citations is the United States with 41 papers, 46716 citations.

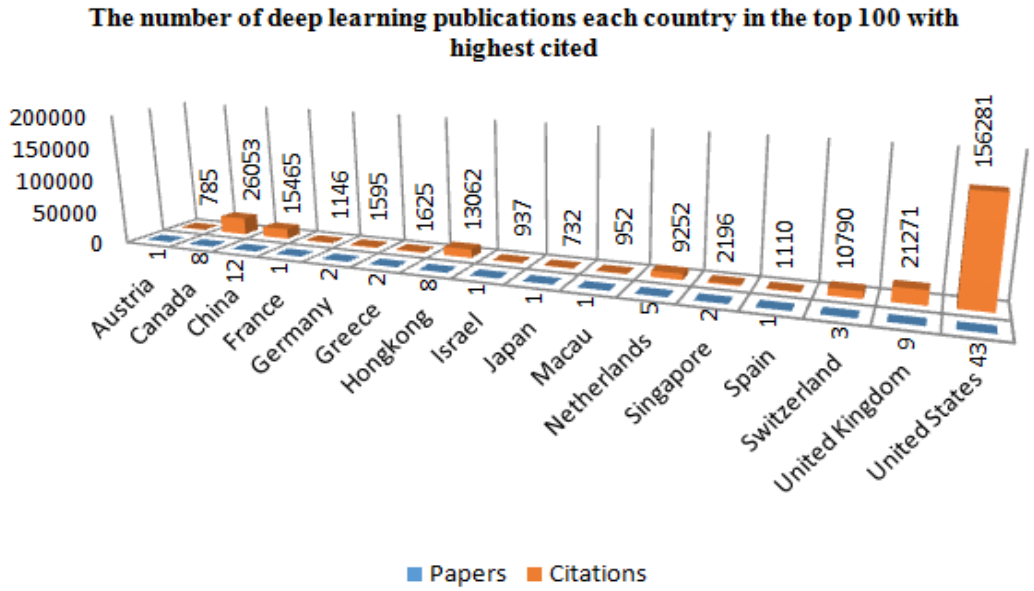

Figure 7b. The number of deep learning publications each country in the top 100 with highest cited

On the topic of deep learning (DL) the countries that are included in the top 100 highest citations in the 2002-2021 range are 16 countries. The country with the most paper publications and the highest citations is the United States with 43 papers, 156281 citations.

Comparison of Machine Learning (ML) and Deep Learning (DL)

Table 5. Comparison between ML and DL seen from the similarities and differences.

Comparison	Machine Learning	Deep Learning
Meaning	A branch of computer science with a focus on developing systems that are able to learn on their own without being explicitly programmed by humans (Saha et al., 2019).	The implementation method of machine learning with the aim of imitating the workings of the human brain using an artificial reasoning network (Saha et al., 2019).
How to solve the problem	By going through initial trials, the problem is solved without being programmed explicitly.	By determining and digesting certain characteristics in a data set.
Algorithm type	1. Supervised Learning 2. Unsupervised Learning 3. Semi-Supervised Learning	1. Deep Neural Network (DNN) 2. Artificial Neural Network (ANN) 3. Convolutional Neural Network (CNN)
Implementation	Useful for helping the community carry out early checks assisted by online medical services or in education, useful for improving the ability to develop teaching aids through	Useful for enhancing the capabilities of virtual assistants like Google Assistant or AlphaGo, deep learning can help classification and also analyze complex data (Korotcov et al., 2017).

Comparison	Machine Learning	Deep Learning
	programming (Korotcov et al., 2017).	
Problem Approach	ML algorithms are capable of processing smaller amounts of data. And to solve the problem it is recommended to break it into several parts so that they can be solved separately, and the solutions are combined to get a complete result.	DL algorithms require large amounts of data and are able to solve the problem as a whole from beginning to end without the need to separate it into several parts.

Table 6. Comparison between ML and DL seen from the advantages and disadvantages

	Machine Learning (ML)	Deep Learning (DL)
Advantages	1. Requires less data 2. Trains on CPU 3. Take less time to train	1. Provides high accuracy 2. Available to tuned in various different ways
Disadvantages	1. Give low accuracy 2. Limited tuning capabilities	1. Requires large data 2. Requires GPU to train properly Take longer time to train

From the presentation of Table 5 and Table 6, it can be seen that ML and DL are similar but not the same. Each has advantages and disadvantages so that it can be a special concern before implementing ML or DL. The process of ML itself begins with input then feature extraction, followed by classification until output is produced. While the DL process begins with input and then continues with two processes simultaneously, namely feature extraction + classification and then output is obtained. So it can be said that the ML process is separated, while the DL process becomes one in the process so that it is shorter but complex. ML in the extraction feature process, there is still human intervention such as (supervised or unsupervised or semi-supervised learning), while DL relies on AI in its learning. The striking thing about the two is that ML requires smaller resources than DL, so outside of many say the DL process is more expensive than ML (illustrated in Figure 8) (Saha et al., 2019).

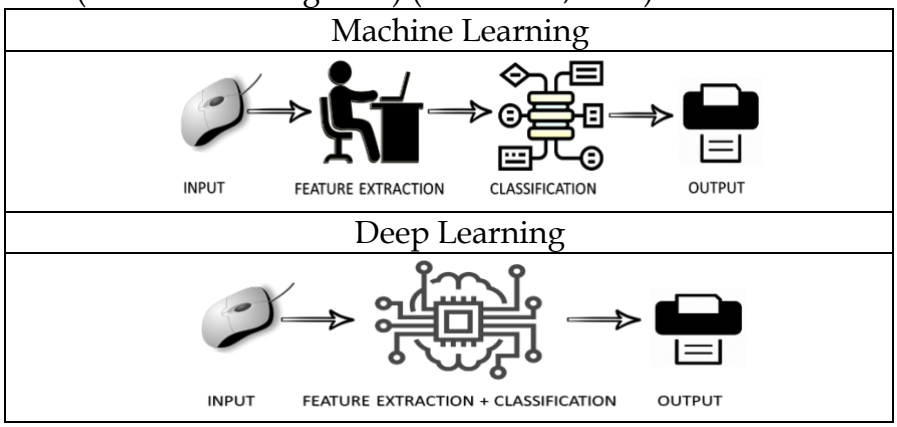

Figure 8. Machine Learning vs Deep Learning.

CONCLUSION

Fundamental Finding : From the research that has been done, it can be concluded that the trend of publishing machine learning (ML) and deep learning (DL) topics has

consistently increased from 2002 to 2021. The most widely published document types in ML are articles, while DL is in the form of conference papers. The highest year-wise distribution of publishing ML and DL occurred in 2017. Author with the highest citation for the ML topic is Pedregosa, while the DL topic is He Kaiming. Both authors are from United States. The United States is also the country that has the highest publication on ML and DL topics in the last 20 years. ML advantages are in terms of requires less data and take less time to train, while the disadvantages are low accuracy and limited tuning capabilities. DL advantages in terms of higher accuracy than ML, available to tuned in various different ways, while the disadvantages are requires large data and take longer time to train. **Implication :** The implications of this research include being able to provide an overview for future researchers regarding the trend of ML and DL topics so that the resulting paper can provide various benefits for the coming year. In addition, it can provide broader knowledge about ML and DL itself. **Limitation :** The limitations of this research is that it cannot access some of the desired journals. **Future Research :** Further research can be carried out more intensively using data based on the Web of Science, in addition to the Scopus database.

REFERENCES

Alberts, B. (2022). Why science education is more important than most scientists think. *FEBS letters*, *596*(2), 149-159. https://doi.org/10.1002/1873-3468.14272

Alghamdi, M. I. (2020). Survey on applications of deep learning and machine learning techniques for cyber security. *International Journal of Interactive Mobile Technologies*, *14*(16), 211-223. https://doi.org/10.3991/ijim.v14i16.16953

Ali, J., Jusoh, A., Idris, N., Abbas, A. F., & Alsharif, A. H. (2021). Nine years of mobile healthcare research: A bibliometric analysis. *International Journal of Online & Biomedical Engineering*, *17*(10). https://doi.org/10.3991/ijoe.v17i10.25243

Belmonte, J. L., Segura-Robles, A., Moreno-Guerrero, A. J., & Parra-González, M. E. (2020). Machine learning and big data in the impact literature: A bibliometric review with scientific mapping in web of science. *Symmetry*, *12*(4), 495. https://doi.org/10.3390/sym12040495

Bharvi, D., Garg, K., & Bali, A. (2003). Scientometrics of the international journal Scientometrics. *Scientometrics*, *56*(1), 81-93. https://doi.org/10.1023/A:1021950607895

Bottou, L., Curtis, F. E., & Nocedal, J. (2018). Optimization methods for large-scale machine learning. *SIAM review*, *60*(2), 223-311. https://doi.org/10.1137/16M1080173

Calabuig-Moreno, F., González-Serrano, M. H., Fombona, J., & Garcia-Tascon, M. (2020). The emergence of technology in physical education: A general bibliometric analysis with a focus on virtual and augmented reality. *Sustainability*, *12*(7), 2728. https://doi.org/10.3390/su12072728

Chen, T., & Tong, Y. (2019). Federated machine learning: concept and applications. *ACM Journals Transactions on Intelligent System and Technology*, *10*(2), 1-19. https://doi.org/10.1145/3298981

Chhapola, V., Tiwari, S., Deepthi, B., & Kanwal, S. K. (2018). Citation classics in pediatrics: A bibliometric analysis. *World Journal of Pediatrics*, *14*, 607-614. https://doi.org/10.1007/s12519-018-0146-6

Conde, A., Arruarte, A., Larrañaga, M., & Elorriaga, J. A. (2020). How can wikipedia be used to support the process of automatically building multilingual domain modules? a case study. *Information Processing & Management*, *57*(4), 102232. https://doi.org/10.1016/j.ipm.2020.102232

Das, P. K. (2013). Journal of informetrics: A bibliometric profile. *DESIDOC Journal of Library & Information Technology,*, *33*(3), 243-252. https://doi.org/10.14429/djlit.33.3.4610

Eck, N. J. V., & Waltman, L. (2013). VOSviewer manual. *Leiden: Univeristeit Leiden*, *1*(1), 1-53.

Eck, N. J. V., & Waltman, L. (2017). Citation-based clustering of publications using CitNetExplorer and VOSviewer. *Scientometrics*, *111*, 1053-1070. https://doi.org/10.1007/s11192-017-2300-7

El Guabassi, I., Bousalem, Z., Marah, R., & Qazdar, A. (2021). Comparative analysis of supervised machine learning algorithms to build a predictive model for evaluating students' performance. *International Journal of Online and Biomedical Engineering*, 17(2), 90-105. https://doi.org/10.3991/ijoe.v17i02.20025

Garg, K. C., & Singh, R. K. (2022). A bibliometric study of papers published in library and information science research during 1994-2020. *DESIDOC Journal of Library & Information Technology*, *42*(1). https://doi.org/10.14429/djlit.42.1.17480

Kevin, W. U. A., Zainab, A. N., & Anuar, N. B. (2009). Bibliometric studies on single journals: A review. *Malaysian Journal of Library & Information Science*, *14*(1), 17-55.

Korotcov, A., Tkachenko, V., Russo, D. P., & Ekins, S. (2017). Comparison of deep learning with multiple machine learning methods and metrics using diverse drug discovery data sets. *Molecular pharmaceutics*, *14*(12), 4462-4475. https://doi.org/10.1021/acs.molpharmaceut.7b00578

Lakin, J. M., & Wai, J. (2022). Developing student aptitudes as an important goal of education. *Gifted Child Quarterly*, *66*(2), 95-97. https://doi.org/10.1177/00169862211039543

Levine, S., Pastor, P., Krizhevsky, A., Ibarz, J., & Quillen, D. (2018). Learning hand-eye coordination for robotic grasping with deep learning and large-scale data collection. *The International journal of robotics research*, *37*(4-5), 421-436. https://doi.org/10.1177/0278364917710318

Li, Y., Xu, Z., Wang, X., & Wang, X. (2020). A bibliometric analysis on deep learning during 2007–2019. *International Journal of Machine Learning and Cybernetics*, *11*(2), 2807-2826. https://doi.org/10.1007/s13042-020-01152-0

Licardo, M., & Leite, L. O. (2022). Collaboration with immigrant parents in early childhood education in Slovenia: How important are environmental conditions and skills of teachers?. *Cogent Education*, *9*(1), 2034392. https://doi.org/10.1080/2331186X.2022.2034392

Limaymanta, C., Apaza-Tapia, L., Vidal, E., & Gregorio-Chaviano, O. (2021). Flipped classroom in higher education: A bibliometric analysis and proposal of a framework for its implementation. *International Journal of Emerging Technologies in Learning (iJET)*, *16*(9), 133-149. https://doi.org/10.3991/ijet.v16i09.21267

Liu, Z-Y. (2020). Online technologies in STEM education". *International Journal of Emerging Technologies in Learning*, *15*(15), 21-31. https://doi.org/10.3991/ijet.v15i15.14677

McNicholas, P. J., Floyd, R. G., Fennimore, L. E., & Fitzpatrick, S. A. (2022). Determining journal article citation classics in school psychology: An updated bibliometric analysis using Google Scholar, Scopus, and Web of Science. *Journal of school psychology*, *90*, 94-113. https://doi.org/10.1016/j.jsp.2021.11.001

Mukherjee, B. (2009). Journal of the american society for information science and technology (2000—2007): A bibliometric study. *IFLA journal*, *35*(4), 341-358. https://doi.org/10.1177/0340035209352429

Mustapha, I., Van, N. T., Shahverdi, M., Qureshi, M. I., & Khan, N. (2021). Effectiveness of digital technology in education during covid-19 pandemic: A bibliometric analysis. *International Journal of Interactive Mobile Technologies*, *15*(8). https://doi.org/10.3991/ijim.v15i08.20415

National Center for Education Statistics. (2020). *Digest of Education Statistics*. NCES 2017-094.

Hashim, K. F., Rashid, A., & Atalla, S. (2018). Social media for teaching and learning within higher education institution: A bibliometric analysis of the literature (2008-

2018). *International Journal of Interactive Mobile Technologies*, *12*(7). https://doi.org/10.3991/ijim.v12i7.9634

Hung, I. C., Yang, X. J., Fang, W. C., Hwang, G. J., & Chen, N. S. (2014). A context-aware video prompt approach to improving students' in-field reflection levels. *Computers & Education*, *70*, 80-91. https://doi.org/10.1016/j.compedu.2013.08.007

Ouatik, F., Erritali, M., Ouatik, F., & Jourhmane, M. (2021). students' orientation using machine learning and big data. *International Journal of Online and Biomedical Engineering*, 17(1), 111-118. https://doi.org/10.3991/ijoe.v17i01.18037

Pande, M., & Mulay, P. (2020). Bibliometric survey of quantum machine learning. *Science & Technology Libraries*, *39*(4), 369-382. https://doi.org/10.1080/0194262X.2020.1776193

Parmar, S., Siwach, A. K., & Kumar, A. (2020). Fifty years research output in oral submucous fibrosis: A bibliometric analysis of publications from 1967 to 2016. *DESIDOC Journal of Library & Information Technology*, *40*(2). https://doi.org/10.14429/djlit.40.02.14727

Patil, N., & Lihitkar, S. (2018). Fifty two years of Library Herald (1958 to 2014). *Library Herald*, *56*(2), 209-232.

Rastegarmoghadam, M., & Ziarati, K. (2017). Improved modeling of intelligent tutoring systems using ant colony optimization. *Education and Information Technologies*, *22*, 1067-1087. https://doi.org/10.1007/s10639-016-9472-2

Sabirova, F., & Kudinov, s. Professional competences in STEM education. (2020). *International Journal of Emerging Technologies in Learning,* 15(14), 179-192. https://doi.org/10.3991/ijet.v15i14.13527

Saha, A., Rathore, S. S., Sharma, S., & Samanta, D. (2019). Analyzing the difference between deep learning and machine learning features of EEG signal using clustering techniques. In *2019 IEEE Region 10 Symposium (TENSYMP)*, 660-664. https://doi.org/10.1109/TENSYMP46218.2019.8971358

Shorten, C., & Khoshgoftaar, T. M. (2019). A survey on image data augmentation for deep learning. *Journal of big data*, *6*(1), 1-48. ttps://doi.org/10.1186/s40537-019-0197-0

Shubina, I., Plakhotnik, O., & Plakhotnik, O. (2021). Professional education and technology usage for establishing methodological competence among future professors: bibliometric analysis. *International Journal of Emerging Technologies in Learning (iJET)*, *16*(19), 235-250. https://doi.org/10.3991/ijet.v16i19.24361

Small, H. (1999). Visualizing science by citation mapping. *Journal of the American society for Information Science*, *50*(9), 799-813. https://doi.org/10.1002/(SICI)1097-4571(1999)50:9<799::AID-ASI9>3.0.CO;2-G

Sobral, S. R. (2021). Two decades of research in e-learning: A deep bibliometric analysis. *International Journal of Information and Education Technology*, 11(9). https://doi.org/10.18178/ijiet.2021.11.9.1541

Wang, Q., Zhou, W., Yang, L., & Huang, K. (2022). Comparison between conventional and deep learning-based surrogate models in predicting convective heat transfer performance of U-bend channels. *Energy and AI*, *8*, 100140. https://doi.org/10.1016/j.egyai.2022.100140

Zahour, O., Benlahmar, E. H., Eddaouim, A., & Hourrane, O. (2020). A comparative study of machine learning methods for automatic classification of academic and vocational guidance questions. *International Journal of Interactive Mobile Technologies (iJIM)*, *14*(8), 43. https://doi.org/10.3991/ijim.v14i08.13005

Zhang, J. Z., Srivastava, P. R., Sharma, D., & Eachempati, P. (2021). Big data analytics and machine learning: A retrospective overview and bibliometric analysis. *Expert Systems with Applications*, *184*, 115561. https://doi.org/10.1016/j.eswa.2021.115561

Zhang, L., Carter Jr, R. A., Qian, X., Yang, S., Rujimora, J., & Wen, S. (2022). Academia's responses to crisis: A bibliometric analysis of literature on online learning in higher education during covid-19. *British Journal of Educational Technology*, *53*(3), 620-646. https://doi.org/10.1111/bjet.13191

Zhao, Z. Q., Zheng, P., Xu, S. T., & Wu, X. (2019). Object detection with deep learning: A review. *IEEE transactions on neural networks and learning systems*, *30*(11), 3212-3232. ttps://doi.org/10.1109/TNNLS.2018.2876865

Zuo, C., Qian, J., Feng, S., Yin, W., Fan, P., Han, J., Qian, K., & Chen, Q. (2022). Deep learning in optical metrology: A review. *Light: Science & Applications, 11*(39), 1-59. https://doi.org/10.1038/s41377-022-00714-x

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