Submited Paper in TEM Journal

20 messages

Binar Kurnia Prahani <binarprahani@unesa.ac.id> Tue, May 10, 2022 at 6:12 AM
To: TEM Journal <temjournal@gmail.com>

Dear Editor TEM Journal

We have conducted collaborative research series; under the title "Digital Learning Research in The Last 30 Years: Important Role of Interactive Learning in Physics"

With research members are as follows:
Dr. Binar Kurnia Prahani, Mila Candra Pristianti , Prof. Dr. Budi Jatmiko, Tan Amelia, M.T., Dr. Firmanul Catur Wibowo

We hope to be able to publish in TEM Journal, as an output of our grant research series. We also are ready to pay publication fees and all rules at TEM Journal.

We hope the entire editorial team is always healthy. Thank you very much for your attention and help.

Best Regards,
Binar Kurnia Prahani
Universitas Negeri Surabaya

Prahani_TEM Journal_Submited 10 05 2022.doc
471K

TEM Journal <temjournal@gmail.com> Tue, May 10, 2022 at 8:20 PM
To: Binar Kurnia Prahani <binarprahani@unesa.ac.id>

Dear Binar Kurnia Prahani,

We have received your manuscript and forwarded it to reviewers.
Thank you for sending.

If your paper pass review processes and meet our standards it is necessary to make the payment.
Publication fee (covers: publishing, review and databases indexing costs): **500** euros.
https://www.temjournal.com/oa/oa.html

Best Regards,
Editorial Board office,
office@temjournal.com
temjournal@gmail.com
www.temjournal.com

[Quoted text hidden]

Binar Kurnia Prahani <binarprahani@unesa.ac.id> Thu, May 26, 2022 at 4:16 AM
To: TEM Journal <temjournal@gmail.com>

Dear Editor

Thank you for your information.

Best Regards,
Binar Kurnia Prahani
Universitas Negeri Surabaya

[Quoted text hidden]

TEM Journal <temjournal@gmail.com> Sun, Jul 31, 2022 at 2:51 PM
To: Binar Kurnia Prahani <binarprahani@unesa.ac.id>

Dear Binar Kurnia Prahani,

The paper originality is good.
We are sending you originality report of the text.
Your work is currently in process of review, and it will be finished as soon as possible.

Best Regards,
Editorial Board office,
office@temjournal.com
temjournal@gmail.com
www.temjournal.com

[Quoted text hidden]

iT Report 95%.pdf
1472K

Binar Kurnia Prahani <binarprahani@unesa.ac.id> Mon, Aug 1, 2022 at 9:30 AM
To: TEM Journal <temjournal@gmail.com>

Dear Editor

We are very happy if our article can be published in the August 2022 edition. We are ready to follow the revision and payment procedures of the TEM Journal. Thank you very much for the information. Healthy and happy greetings to the editor.

Best Regards
Dr. Binar Kurnia Prahani
Universitas Negeri Surabaya

[Quoted text hidden]

TEM Journal <temjournal@gmail.com> Sun, Aug 7, 2022 at 1:58 AM
To: Binar Kurnia Prahani <binarprahani@unesa.ac.id>

Dear Binar Kurnia Prahani,

When there are several consecutive citations then write: [1], [2], **Not ([1]-[2], [1-2], [1, 2]**), (**not more than two or three**).

Preferably, all references should be visible in Google Scholar.
References should be presented in **a full form** in the same way as they are presented in Google Scholar (APA style).

You have used a large number of references.
You need to reduce this number up to 30-35.
Please delete some of the references that aren't visible in Google Scholar.

We reviewed the first 3 references.
See COMMENTS in attach.
Again check other references you have used.
If they are not visible or are incomplete, you should correct or delete them.

If you are interested, your paper could be published in this issue of the journal (in last week of August, 2022), provided you swiftly respond to the reviewers' remarks.

You should submit us as soon as possible the corrected paper.

Best Regards,
Editorial Board office,
office@temjournal.com
temjournal@gmail.com
www.temjournal.com

[Quoted text hidden]

Binar Kurnia Prahani <binarprahani@unesa.ac.id> Sun, Aug 7, 2022 at 10:59 AM
To: TEM Journal <temjournal@gmail.com>

Dear Editor TEM Journal

We hope this article can be published in August 2022. The revision version is in the attachment.
Keep healthy and happy.
Thank you very much

Best Regards,
[Quoted text hidden]

Prahani_TEM Journal_Revised 07 08 2022.doc
193K

TEM Journal <temjournal@gmail.com> Tue, Aug 9, 2022 at 3:57 AM
To: Binar Kurnia Prahani <binarprahani@unesa.ac.id>

Dear Binar Kurnia Prahani,

Preferably, all references should be visible in Google Scholar.
References should be presented in **a full form** in the same way as they are presented in Google Scholar (APA style).

Rearrange references in APA style, for example:
[1]. Hemmasian Kashania M.M., & Dobregob K.V. (2013). Heat and mass transfer in natural draft cooling towers, *Journal of Engineering Physics and Thermophysics,* 86(5), 1072-1082.

We reviewed a few references.
Again check other references you have used.
If they are not visible or are incomplete, you should correct or delete them.
Reviewer asked for you to correct text indicated in the COMMENTS.

After the corrections you should send us your paper again as soon as possible.

Best Regards,
Editorial Board office,
office@temjournal.com
temjournal@gmail.com
www.temjournal.com

[Quoted text hidden]

COMMENTS-2.docx
213K

Binar Kurnia Prahani <binarprahani@unesa.ac.id> Tue, Aug 9, 2022 at 9:27 AM
To: TEM Journal <temjournal@gmail.com>

Dear Editor TEM Journal

We hope this article can be published in August 2022. The revision version is in the attachment.
[Quoted text hidden]

COMMENTS-2 Revised 09 08 2022.doc
299K

TEM Journal <temjournal@gmail.com> Tue, Aug 9, 2022 at 9:29 PM
To: Binar Kurnia Prahani <binarprahani@unesa.ac.id>

Dear Binar Kurnia Prahani,

We reviewed a few references.
Reviewer asked for you to correct text indicated in the COMMENTS.
References that are not visible in Google Scholar and exist, display them via the DOI number.
Again check other references you have used.
If they are not visible or are incomplete, you should correct or delete them.

After the corrections you should send us your paper again as soon as possible.

Best Regards,
Editorial Board office,
office@temjournal.com
temjournal@gmail.com
www.temjournal.com

[Quoted text hidden]

COMMENTS-3.docx
207K

Binar Kurnia Prahani <binarprahani@unesa.ac.id> Wed, Aug 10, 2022 at 2:40 AM
To: TEM Journal <temjournal@gmail.com>

[Quoted text hidden]

COMMENTS-3 Revised 10 08 2022.docx
195K

TEM Journal <temjournal@gmail.com> Wed, Aug 10, 2022 at 6:36 PM
To: Binar Kurnia Prahani <binarprahani@unesa.ac.id>

Dear Binar Kurnia Prahani,

Reviewer asked for you to correct text indicated in the COMMENTS.
Again check other references you have used.

Best Regards,
Editorial Board office,
office@temjournal.com
temjournal@gmail.com
www.temjournal.com

[Quoted text hidden]

COMMENTS-4.docx
217K

Binar Kurnia Prahani <binarprahani@unesa.ac.id> Thu, Aug 11, 2022 at 6:10 AM
To: TEM Journal <temjournal@gmail.com>

[Quoted text hidden]

COMMENTS-4 Revised 11 08 2022.docx
192K

TEM Journal <temjournal@gmail.com> Fri, Aug 12, 2022 at 12:51 AM
To: Binar Kurnia Prahani <binarprahani@unesa.ac.id>

Dear Binar Kurnia Prahani,

The paper has been **accepted by the reviewers**.
At the moment it is undergoing a language verification.
Soon we will inform you about the complete review.

Best Regards,
Editorial Board office,
office@temjournal.com
temjournal@gmail.com
www.temjournal.com

[Quoted text hidden]

TEM Journal <temjournal@gmail.com> Fri, Aug 12, 2022 at 4:12 PM
To: Binar Kurnia Prahani <binarprahani@unesa.ac.id>

Dear Binar Kurnia Prahani,

You have many language mistakes.
We have corrected language errors and we are sending them for you to see what we have done (**COMMENTS-6**). You do not need to send a correction unless you have a comment on the language alterations we did.

You should perform many language corrections indicated in **COMMENTS-7**.
You should revise the stated corrections in this version of the paper (COMMENTS-7), which is reviewed.

After the corrections you should send us your paper again as soon as possible.

Best Regards,
Editorial Board office,
office@temjournal.com
temjournal@gmail.com
www.temjournal.com

[Quoted text hidden]

2 attachments

COMMENTS-6.docx
223K

COMMENTS-7.docx
221K

Binar Kurnia Prahani <binarprahani@unesa.ac.id> Sat, Aug 13, 2022 at 8:33 AM
To: TEM Journal <temjournal@gmail.com>

Dear Editors of TEM Journal

We agree with the performance of the article that has been done. The revision version is in the attachment.
We hope this article can be published in August 2022.
Keep healthy and happy.
[Quoted text hidden]

COMMENTS-7_Revised.doc
329K

TEM Journal <temjournal@gmail.com> Sat, Aug 13, 2022 at 5:06 PM
To: Binar Kurnia Prahani <binarprahani@unesa.ac.id>

Dear Binar Kurnia Prahani,

Your paper "Digital Learning Research in the Last 30 Years: Important Role of Interactive Learning in Physics" **has been accepted** to be published and printed in the TEM Journal Vol.11, No.3, (in the last week of August, 2022).
Please sign the copyright agreement form, and send a scanned copy back to us.
Publication fee - APC (covers: publishing, review and databases indexing costs): **500** euros.

It is necessary to make the payment within **5 days**.
After payment, please inform us.

Closer guidelines for the payment:

If you are paying personally (if APC is not covered by your institution or fund), you can choose to pay by bank transfer into our official bank account, in any bigger bank (You have swift code and all necessary information in the attached document). **OR you can pay online** (PayPal or Debit, Credit Card) following this link:
https://www.temjournal.com/apc/apc.html

If your institution pays for you, it is necessary to pay into our official bank account through Bank Transfer.
You have swift code and all necessary information in the attached document:

Swift code is: MEBARS22
Our bank is: CREDIT AGRICOLE SRBIJA AD, Novi Sad
Name of our company: **UIKTEN**
Address: Hilma Rozajca 15, Novi Pazar
Our account is: RS35330007140004630609
Country: Republic of Serbia

When you make the payment, you need to choose OUR (you need to cover all transfer charges).

After the payment you will receive Invoice, or you can request one before payment, if your institution or bank needs one. In that case please write all necessary information (full name of institution, full address, VAT number, number of grants- if any, etc..).

Reminder:
Your paper must not be published elsewhere (journal, conference, etc.), in substantially the same form, in English or in any other language.

You can find Camera-ready paper in the attachment.
Confirm that everything is OK.

Best Regards,

Editorial Board office,
office@temjournal.com
temjournal@gmail.com
www.temjournal.com

[Quoted text hidden]

3 attachments

Copyright Agreement Form.pdf
37K

Payment methods - Journal Publication - UIKTEN.pdf
451K

Camera-ready.docx
209K

Binar Kurnia Prahani <binarprahani@unesa.ac.id> Wed, Aug 17, 2022 at 7:40 AM
To: TEM Journal <temjournal@gmail.com>

Dear Editor

We have done the payment (attached). Thank you very much

Best Regards,
[Quoted text hidden]

2 attachments

Payment TEM Journal_Binar Kurnia Prahani et al.pdf
93K

Copyright Agreement Form_Binar Kurnia Prahani et al.pdf
211K

TEM Journal <temjournal@gmail.com> Thu, Aug 18, 2022 at 12:09 AM
To: Binar Kurnia Prahani <binarprahani@unesa.ac.id>

Dear Binar Kurnia Prahani,

We have received your payment and copyright agreement form.
You can find Invoice for your payment in the attachment.

We will inform you after publishing your paper (in the last week of August, 2022).

Best Regards,
Editorial Board office,
office@temjournal.com
temjournal@gmail.com
www.temjournal.com

[Quoted text hidden]

41 - Invoice.pdf
317K

Binar Kurnia Prahani <binarprahani@unesa.ac.id> Thu, Aug 18, 2022 at 12:43 AM
To: TEM Journal <temjournal@gmail.com>

Dear Editor

Thank you very much

Best Regards

Binar Kurnia Prahani
Universitas Negeri Surabaya
[Quoted text hidden]

TEM Journal. Volume .., Issue .., pages .., ISSN .., DOI: .., 2022.

Digital Learning Research in The Last 30 Years: Important Role of Interactive Learning in Physics

Binar Kurnia Prahani [1(✉)], Mila Candra Pristianti [1], Budi Jatmiko [1], Tan Amelia [2], Firmanul Catur Wibowo [3]

[1] *Universitas Negeri Surabaya, Surabaya, Indonesia*
[2] *Universitas Dinamika, Surabaya, Indonesia*
[3] *Universitas Negeri Jakarta, Jakarta, Indonesia*
✉*binarprahani@unesa.ac.id*

Abstract **– The aim is to analyze top 100 highest citations of digital learning topic, and the important role of interactive learning in physics learning in 1992-2021. This study uses bibliometric analysis and literature review. The trend of digital learning topics is increase steadily, from 2014 to 2021. Digital learning show an excellent contribution to physics. The important role of interactive learning in physics are to improve student learning outcomes, deepen understanding and make learning more interesting. More intensively, further research can be carried out by comparing other learning systems applied in physics learning.**

Keywords **– Bibliometric, Digital Learning, Physics Learning**

1. Introduction

Various kinds of learning system have been applied according to surrounding conditions, the examples is digital learning. The development of learning systems must pay attention to the ease of adaptation and transformation [1]-[3]. Learning development can be done by combining organizational learning theory and general systems theory. Learning must be sustainable and flexible even in unforeseen conditions [4].

There are many impacts of the covid-19 pandemic, one of which is in the world of education. One of the updates on October 10, 2021, the entire country has reported 219 million cases with 4.55 million deaths [5]. With the danger that threatens, many countries are trying to make learning sustainable [6]. Efforts are made to organize healthy learning during the covid-19 pandemic crisis [7]. The covid-19 outbreak caused the closure of schools and colleges, so that educational institutions designed more flexible. Research conducted by Leonhard [8], Neil [9], and David [10] concluded that during the covid-19 pandemic, student responses showed good acceptance of digital learning. Students accept and adapt easily to digital technology during the covid-19 pandemic.

Physics learning is closely related to natural phenomena and experimental activities. The flexible of physics learning can be done use digital technology or without it [11]-[14]. By learning physics through digital learning students are challenged to be more independent, must be easy to adapt and willing to learn [15]. However, there are shortcomings in the implementation of digital learning, namely some places have limited access to digital media, and potential dependence on digital technology [16]-[18]. Mentoring and supervision by physics teachers will determine the success of digital learning [19]-[20].

From existing studies, there is still no discussion that show the contribution digital learning in physics learning and important role of interactive learnig in physics. Some studies tend to discuss digital

DOI: 10.18421/TEMxx-xx
https://doi.org/10.18421/TEMxx-xx

Corresponding author: Binar Kurnia Prahani, Universitas Negeri Surabaya

Email: binarprahani@unesa.ac.id

Received: -----.
Accepted: -----.
Published: -----.

learning, but to show the right data regarding the analysis, blibiometric studies and literature reviews are needed. Bibliometric analysis is a method to provide knowledge regarding the growth and flow of literature in a particular publication field [21]. This bibliometric study uses empirical data to track existing publications [22]-[25]. This study can analyze the distribution of manuscripts sorted by country, source, year and more [26].

With an explanation of the importance digital learning as well as the existing shortcomings, this research was carried out. The aim is to analyze top 100 highest citations of digital learning topic, and the important role of interactive learning in physics from 1992 to 2021. For analysis using bibliometrics and also literature review. The objective research include :

1. Analyze the trend of digital learning publications from the last thirty years.
2. Identify the most widely used keywords, the country and author that contribute the most to the publication of digital learning in last thirty years.
3. Identify document types and source titles for digital learning from the last thirty years.
4. Identify the year wise distribution of the top 100 cited digital learning publications from the last thirty years
5. Identify the contribution digital learning in physics learning over the last thirty years
6. Identify the advantages and disadvantages of digital learning
7. Analyze the important role of interactive learning in physics

2. Methods

This study uses bibliometric analysis and literature review. The data used in this study were taken from Scopus. Scopus is well-known for its largest database of publications in various fields including academics [27]-[29]. Data from Scopus can be adjusted according to the needs of the year, title, country, keywords, and so on [30]-[32]. In addition, this study uses a literature review from previous studies as a reinforcement of research data [33].

Research data taken on April 1, 2022. The data in Scopus is selected based on the keywords you want to search for. In this study, the keyword selection stage was carried out twice, the first regarding digital learning. Furthermore, the second keyword are connected with physics learning to find the contribution of digital learning. The data obtained in the form of .csv which was then analyzed using microsoft excel and .ris which was analyzed using VOSviewer [34]-[35].

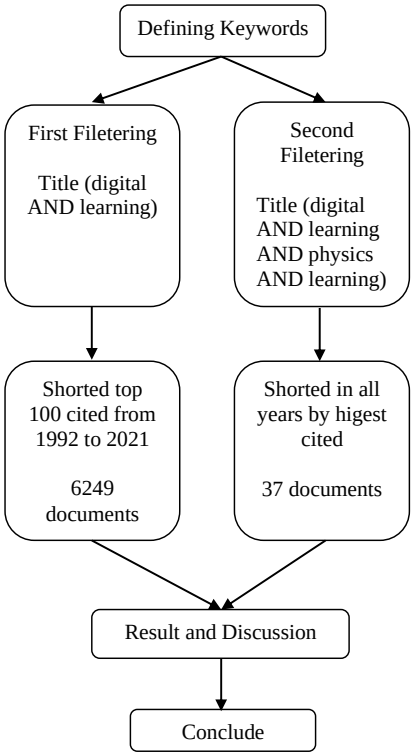

Figure 1. Flowchart for the keyword filtering

3. Result and Discussion

3.1 Publication Trend in Last 30 Years

From Figure 2, we can see the trend of publications related to digital learning. The trend of publication is an important aspect to pay attention to and follow up [36]. Considering that publications must be in accordance with current conditions, which mean the development of a topic is determined from the trend of publications each year [37].

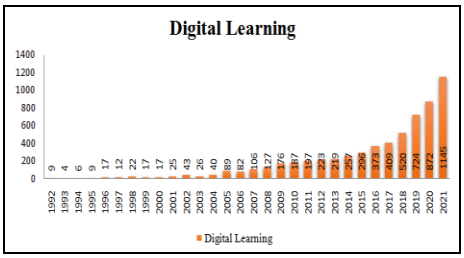

Figure 2. Digital learning publication trends

The highest digital learning publication in 2021 with 1145 documents and the lowest in 1993 with 4 documents. Digital learning publications began to increase steadily, from 2014 to 2021. The highest increase occurred in 2021 as many as 273 documents from 2020. The researchers tend to be interested in raising the topic of digital learning [38]-[39]. This is in line with the fact that the majority of education in the world has used digital learning due to the emergence of the covid-19 pandemic [40]. So that research related to digital learning has high potential for future research.

3.2 Visualization of The Most Used Keywords, Top Countries and Top Authors Who Contributed The Most

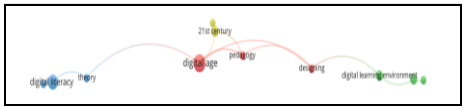

Figure 3. The keywords visualization of digital learning

Figure 3 shows sthe keyword visualization using VOSviewer. Keywords can describe the subject matter in a publication [41]-[43]. For digital learning topics, the most commonly used keyword is "digital age" which has 8 occurrences and "digital literacy" has 6 occurrences.

Table 1. *Comparison of the top 10 countries with the most publications in the last thirty years*

Top 10 countries	Publications
United States	1,359
United Kingdom	460
China	422
Germany	347
Australia	319
Taiwan	306
Spain	281
Indonesia	221
Canada	208
India	187

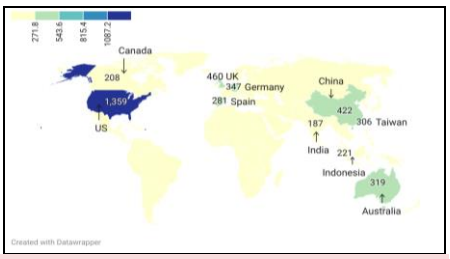

Figure 4. *Top 10 Countries with publications about digital learning*

From Table 1 and Figure 4, it can be concluded that the United States has the highest contribution over the last thirty years both on the topic of digital learning. There are five countries that consistently occupy the top 10 on all publication topics related to digital learning including the United States, China, United Kingdom, Australia and Spain. To identify the author who has the most publications on each topic of digital learning, using VOS viewer and Microsoft Excel analysis. The results of the Microsoft Excel analysis are shown in Table 2.

Table 2. *The top 10 author with the highest citations in the last thirty years*

Author	Total Citations	Country
M. Papastergiou	1,880	Greece
K. Kiili	1,978	Findland
C.M. Greenhow	2,509	United States
A.R. Janowczyk	1,269	United States
D.B. Clark	3,069	Canada
A. Madabhushi	14,845*	United States
B. Gros	660	Spain
S. Erhel	429	France
A. Sadik	367	Egypt
B.Q. Huynh	590	United States

Table 2 shows the top 10 authors from the highest citations for the topic of digital learning, M. Papastergiou from Greece. Meanwhile, the highest total citation was owned by A Madabhushi came from the United States. To find out who the author on the topic of digital learning is the most contributing and connected is using VOSviewer. With VOSviewer we can identify the classification of top authors [44]. The grouping and connection of each author is indicated by the presence of clusters [45]-[46]. The first result of the digital learning topic is divided into 3 clusters, namely red (n=5), green (4), blue (n=2). H. Beetham is the main author because he has 3 documents with 2 total link strength which is more than any other author.

3.3 The Document Types and Source Titles of Top 100 Highest Cited Publication in Last 30 Years

Table 3. *The document types of top 100 highest cited digital learning publication in last 30 years*

Document Type	Freq-uency	Cited	Mean	Med-ian	SD
Article	81*	14206*	175.3	125	160.8*
Conference paper	7	808	115.4	95	47.2
Review	4	810	202.5*	209.5*	96.6
Note	0	0	0	0	-
Book	7	1011	144.4	129	63.1
Editorial	1	376	376	376	-

Table 3 shows on digital learning topic, the most publications are in the form of articles (n=81). Digital learning have the total cited is 14,206. The standard deviation is quite high, namely digital learning (n=160.8).

Table 4. *The source titles of top 100 highest cited publication in last 30 years*

Source Title	TD	TC
Computers and Education	13	2983
Educational Technology and Society	4	415
Journal of Computer Assisted Learning	3	565
Journal of Research on Technology in Education	3	530
Language and Learning in the Digital Age	3	468
Geoderma	3	386
ReCALL	3	325
Internet and Higher Education	2	1008
Rethinking Pedagogy for a Digital Age: Designing and Delivering E-Learning	2	343
Learning, Media and Technology	2	264
TD = Total Documents TC = Total Citations		

Table 4 shows the source titles of digital learning are varied. For the highest source title digital learning namely Computers and Education (n=13 documents). The highest total citation is 2,983 namely source title is Computers and Education.

3.4 The Year Wise Distribution of Top 100 Highest Cited Publication in Last 30 Years

Table 5 contains information on the distribution of the top 100 cited publications on the topics of digital learning. The range of data used is from 1992 to 2021.

Table 5. *The year wise distribution of top 100 highest cited publication in last 30 years*

Year	Citable Year	Digital Learning			
		TC	TD	ACPP	ACPPY
1992	30	0	0	0	0
1993	29	0	0	0	0
1994	28	0	0	0	0
1995	27	215	2	107.5	3.9
1996	26	0	0	0	0
1997	25	0	0	0	0
1998	24	0	0	0	0
1999	23	0	0	0	0
2000	22	0	0	0	0
2001	21	420	2	210	10
2002	20	0	0	0	0
2003	19	0	0	0	0
2004	18	454	2	227	12.6
2005	17	1237	4	309.2*	18.2
2006	16	270	2	135	8.4
2007	15	891	5	178.2	11.8
2008	14	869	5	173.8	12.4
2009	13	2282	7	326	25.1
2010	12	421	3	140.3	11.6
2011	11	932	7	133.1	12.1
2012	10	1327	10	132.7	13.3
2013	9	1199	7	171.3	19
2014	8	894	8	111.7	13.9
2015	7	443	4	110.7	15.8
2016	6	2699*	11*	245.4	40.9
2017	5	567	4	141.7	28.4
2018	4	881	6	146.8	36.7
2019	3	884	9	98.2	32.7
2020	2	326	2	163	81.5*
2021	1	0	0	0	0
*The Highest Number					

This information can be used to see in what year the top 100 cited publications were produced on the topic. From this study it was found that the highest year is 2016 (n=11 documents). In addition, from this study it was found that the highest year is 2016 (n=2,699 citations). The highest average citation per paper per year in 2020 is 81,5.

3.5 Literature Review of Digital Learning to Physics Learning

Table 6 contains the results of the literature review by taking into account the quartiles, citations, and findings to provide recommendations regarding the selected paper.

Table 6. *Top 5 highest cited paper showed contribution of digital learning to physics learning*

Author	SJR	Citation	Findings
J.L. Anderson and M. Barnett [47]	1,03 (Q1)	46	Digital learning with game simulations has a positive impact on the learning outcomes of junior high school students in physics learning.
P. Sengupta, K.D. Krinks, D.B. Clark [48]	4,06 (Q1)	22	The results of the study show that the combination of using digital learning fosters student physics learning motivation
M. Melo[49]	0,54 (Q2)	4	The use of digital learning 4C/ID model in physics content to students has a positive impact on learning outcomes.
E. Euler, C. Prytz, B. Gregorcic [50]	0,34 (Q3)	1	Digital learning using the Algodoo application gives students the opportunity to explore physics learning materials for free and able to attract students' attention in learning
Sukarno, and M.E. Widdah [51]	0,49 (Q2)	1	Students' metacognitive and digital literacy skills increase in physics learning.

The ranking system of reputable journals based on the subject or category of the related journal field is also called quartiles [52]. From these results, it can be seen that the topic of digital learning has the highest citation is 46, thus, research related to digital learning in physics will have a lot of potentials, and its novelty will be quite high. Digital learning tends to take advantage of interactive learning applications to increase student motivation and learning outcomes [53].

3.6 Advantage and Disadvantage of Digital Learning to Physics Learning

Table 7. *Discussion about digital learning*

Discussion	Digital Learning
Meaning	Learning media that can be done digitally without having to wait for internet access to start.
Characteristics	• Some digital learning can be accessed without internet • Not tied to face-to-face or non-face-to-face learning • More towards the learning media
Advantage	Can be used in various places, can trigger students to think creatively and innovatively
Disadvantage	Can lead to dependence on digital tools so that it can cause laziness in students

Broadly speaking, it can be concluded that digital learning have advantages in flexibility and types of media that utilize sophisticated digital tools. While the disadvantages have an impact on students' lifestyles which can become dependent on digital learning media. The digital learning is a learning process that requires internet access, while digital learning does not always require internet access [54].

3.7 Analyze the Important Role of Interactive Learning in Physics Based on Digital Learning Research

Learning physics still tends to be difficult for most students to understand. Physics learning needs to be set more interactively for students [55]. The use of interactive learning media can be integrated using a combination of video, graphics, text, and sound [56]. Digital learning by applying interactive virtual reality can deepen students' understanding of physics material [57]-[58]. In addition, through good quality worksheets in digital learning can improve students' critical thinking skills in learning physics [59]. Practical activities can play an important role in engaging students with the world of science, especially when using digital tools [60]. So it can be concluded that interactive learning can improve student learning outcomes [61].

The majority of students in the 21st century are proficient in advanced technology and are adaptable. For example, digital learning with interactive simulations positively affects student physics learning outcomes [62]. In addition, the use of interactive modules is also very important to apply because, according to research [63], digital learning of physics with interactive modules shows compatibility and a positive impact. So that the important role of using interactive media in physics is to improve students' abilities, one of which is the ability to think critically.

Since the last three years, the world has been affected by the pandemic, so academic units must also think about effective learning methods that can still improve student achievement. Therefore, interactive learning in physics is starting to be more widely applied [64]. One of them is by using interactive multimedia, which is able to improve students' understanding of concepts [65]. Interactive learning plays an important role in deepening the concept of physics and making the learning atmosphere more interesting even though digital learning [66].

4. Conclusion

Research results analysis using bibliometric studies and literature reviews related to digital learning get several conclusions. The conclusion is that the trend of digital learning topics is increase steadily, from 2014 to 2021. The most commonly used keywords are digital age, and digital literacy. United States (US) has made the highest contribution over the last thirty years on digital learning. The author with the highest citation on digital learning is M. Papastergiou from Greece. The type of document that is often published in the article. The highest source titles digital learning, namely Computers and Education.The highest average citation per paper per year is in 2020 where digital learning (n=81,5). The digital learning topic contribute to learning physics. From explanation above, the future research related to digital learning in physics will have a lot of potentials, and its novelty will be quite high. The important role of interactive learning in physics is to improve student learning outcomes, train critical thinking skills, deepen understanding of concepts and make learning more interesting. The advantages in flexibility and types of media that utilize sophisticated digital tools. While the disadvantages have an impact on students' lifestyles which can become dependent on digital learning media and because it’s using the internet network, which requires costs and a strong signal because not all areas have a strong network connection.

The implication of this research is to show the trend of publication of digital learning topics so that

future researchers can show more benefits related to these topics. With this article, researchers can find out the strengths and weaknesses of digital learning topic and can find updates for future research. The limitation of the study is that some research results at Scopus are limited to full access. More intensively, further research can be carried out by comparing other learning systems applied in physics learning.

5. Acknowledgement

The author's gratitude goes to the *Direktorat Jenderal Pendidikan Tinggi, Riset, dan Teknologi; Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, Indonesia* who has supported funding.

References

[1] C. C. Huei. (2014). "An adaptive scaffolding e-learning system for middle school students' physics learning". *Australasian Journal of Educational Technology*, vo. 30, no. 3, pp. 342-355.

[2] C. E. Dias, M. V. Aymore, R. V. Choelho, D. R. V. Eloy, C. L. A. Carvalho, G. R. Machado, D. F. A. Moreira, D. M. F. L. Lopes, O. A. L. Sandoval, B. Remis, D. S. Rafael. (2021). "Development and evaluation of an intelligence and learning system in jurisprudence text mining in the field of competition defense". *Applied Science Switzerland*, vol. 11, no. 23.

[3] H. F. Hui, L. I. Hsiu, Y. H. Chin, C. N. Shing. (2022). "Effect of Socratic reflection prompts via video-based learning system on elementary school students' critical thinking skills". *Computers and Education*,vol. 183.

[4] Z. Youness, D. Rachid, T. Mohamed. (2018). "Multi-criteria analysis and advanced comparative study between M-learning development approaches".*International Journal of Interactive Mobile Technologies*, vol. 12, no. 3, pp. 38-51.

[5] T. Hassan. (2022). "A global update on covid-19 pandemic". Proceedings of the Pakistan Academy of Sciences: B. Life and Environmental Sciences, vol. 58, no.4, pp. 1-4.

[6] D. Cristine, B. Hillary, A. J. Subih, C. K. Maya, A. Wesley, M. Erik, and K. Petra. (2022) "I will teach you here or there, I will try to teach you anywhere: perceived supports and barriers for emergency remote teaching during the COVID-19 pandemic".*International Journal of STEM Education*, vol. 9, no. 1.

[7] T. Dincer. (2022) "Reflexes of international organizations regarding education in the covid-19 pandemic process and comparing implementations in turkey". *Milli Egitim*, vol. 51, no. 233, pp.887-909.

[8] O. G. Leonhard, Z. J. S. Maria, S. Lisa, T. F. Zoltan, H. Amr, R. M. Philipp, F. Sebastioan, S. E. Franz, R. J. Caroline. (2021). "Students' attitudes toward digital learning during the covid-19 pandemic: a survey conducted following an online course in gynecology and obstetrics". *Archives of Gynecology and Obstetrics*, vol. 304, no.4, pp. 957-963.

[9] G. Neil, V. Dominique, B. David, L. Lin, T. Joanna, B. Silvia. (2022). "The post-COVID-19 future of digital learning in higher education: Views from educators, students, and other professionals in six countries". *British Journal of Educational Technology*.

[10] A. David, A. Samuel, G. B. Juliet. (2022). "Covid-19 pandemic and the shift to digital learning: experiences of students in a community college in ghana". *Community College Journal of Research and Practice*, vol. 46, no. 1-2, pp. 101-112.

[11] R. B. Prigo, A. Korda, W. C. Walker. (1975). "Multipurpose physics learning center: A working model". *American Journal of Physics*, vol. 42, no. 12, pp. 1049-1053.

[12] G. Ronald, N. Lisa. (1997) "Concepts first - A small group approach to physics learning". *American Journal of Physics*, vol. 65,no. 5, pp. 418-428.

[13] E. Christophe. (2000). "Physics learning through a telecommunications context".*Physics Education*, vol. 35, no. 4, pp. 240-244.

[14] C. Poluakan, and D. Katuuk. (2021). "PIMCA: a new alternatives to physics learning model". *Journal of Physics: Conference Series*, vol. 2165, no. 1.

[15] K. T. Feng, P. H. Tseng, P. S. Chiu, J. L. Yang, C. J. Chiu. (2013). "Covid 19-A major cause of digital transformation in education or just an evaluation test". Proceedings of SPIE - The International Society for Optical Engineering, vol. 8649.

[16] Pal'Ova', N. M. Novak, V. Weidinger. (2017). "Digital learning as a tool to overcome school failure in minority groups". International Convention on Information and Communication Technology, Electronics and Microelectronics, pp. 767-772.

[17] N. Ratnaningsih, K. Ni'Mah, E. Hidayat. (2020). "Covid-19 the earliest for digital learning in mathematics: an overview from technology literacy". Journal of Physics: Conference Series, vol. 1819, no. 1.

[18] I. T. Pavin. (2022). "The lack of academic social interactions and students' learning difficulties during covid-19 faculty lockdowns in Croatia: the mediating role of the perceived sense of life disruption caused by the pandemic and the adjustment to online studying". *Journal Social Science*, vol. 11, no. 2.

[19] D. Dewantara, M. Misbah, S. Haryandi, S. Mahtari. (2020). "Game-based learning for the mastery of HOTS in prospective physics teachers in digital electronics courses". Journal of Physics: Conference Series, vol. 1869, no. 1.

[20] R. Vieyra, J. Himmelsbach. (2022). "Teachers' disciplinary boundedness in the implementation of integrated computational modeling in physics". *Journal of Science Education and Technology*, vol. 31, no. 2, pp. 153-165.

[21] K. F. Hashim, A. Rashid, S. Atalla. (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*, vol. 12, no. 7, pp. 4-19.

[22] Estabrooks, C. A., Winther, C., & Derksen. (2004). "Mapping the field: a bibliometric analysis of the research utilization literature in nursing". *Nursing Research*, vol. 53, no. 5, pp. 293–303.

[23] A. Jose, C. Ciro, M. Corrado. (2018). "A bibliometric analysis of the explainable artificial intelligence research field". *Communications in Computer and Information Science*, vol. 853, pp. 3-15.

[24] S. S. Rolland. (2020). "Mobile learning in higher education: A bibliometric review". *International Journal of Interactive Mobile Technologies*, vol. 14, no. 11, pp. 153-170,.

[25] D. Dewantara, E. W. N. Sofianto, Misbah, D. Munawaroh. (2021). "Physics e-module: A review and bibliometric analysis". *Journal of Physics: Conference Series*, vol. 2104, no. 1.

[26] M. Ishamuddin, V. N. Thuy, S. Masoumeh, Q. H. Imran, K. Norman. (2021). "Effectiveness of digital technology in education during covid-19 pandemic. a bibliometric analysis". *International Journal of Interactive Mobile Technologies*, 15, no, 8, pp. 136-154.

[27] T. Tavukcu, A. M. Kalimullin, A.V. Litvinov, N. N. Shindryaeva, V. Abraukhova, N. M. Abdikeev. (2020). "Analysis of Articles on Education and Instructional Technologies (Scopus)". *International Journal of Emerging Technologies in Learning*, vol.15, no. 23, pp. 108-120.

[28] W. Jiaxing, S. Lihua, Z. Wuyuan. (2021). "A bibliometric analysis of quantum computing literature: mapping and evidences from Scopus".*Technology Analysis and Strategic Management*, vol. 33, no. 11, pp. 1347-1363.

[29] K. W. M. I. W. Mohamad, N. A. M. Nasir, N. A. S. M. Hamidi, Y. Nusaibah, M. S. Shaifudin, A. M. A. A. M. Suhaimi, M. A. Badruddin, A. Adnan, W. M N. W. Nik, M. S. M. Ghazali. (2022). "25 years of progress on plants as corrosion inhibitors through a bibliometric analysis using the Scopus database (1995–2020)". *Arabian Journal of Chemistry*, vol. 15, no. 4, pp. 4-19.

[30] Z. Genc, A. R. Masalimova, R. I. Platonova, Z. M. Sizova, O. V. Popova. (2019) "Analysis of documents published in Scopus database on special education learning through mobile learning: A content analysis". *International Journal of Emerging Technologies in Learning*, vol. 14, no. 22, pp. 192-203.

[31] B. V. Nurdin, S. S. Hutagalung, Yulianto, R. C. Kurniawan, D. Hermawan. (2020) "Bibliometric analysis on governance index topics using Scopus database and vosviewer". *Journal of Physics: Conference Series*, vol. 1933, no. 1.

[32]P. Kulkanjanapiban, and T. Silwattananusarn. (2022). "Comparative analysis of Dimensions and Scopus bibliographic data sources: An approach to university research productivity". *International Journal of Electrical and Computer Engineering*, vol. 12, no.1, pp. 706-720.

[33] R. Girwidz, L. J. Thoms, H.Pol, V. Lopez, . Michelini, A. Stefanel, T. Greczylo, A. Muller, B. Gregorcic, M. Homostrei. (2019). "Physics teaching and learning with multimedia applications: a review of teacher-oriented literature in 34 local language journals from 2006 to 2015". *International Journal of Science Education*, vol. 41, no. 9, pp. 1181-1206.

[34] N.J.V. Eck and L. Waltman. (2013) "VOSviewer manual". *Leiden: University Leiden*, vol. 1, no. 1, pp. 1-53.

[35] C. R. Putri, S. M. Soleh, A. Saregar, A. Anugrah, N. E. Susilowati. (2021). "Bibliometric analysis: Augmented reality-based physics laboratory with VOSviewer software". *Journal of Physics: Conference Series*, 1798.

[36] C. Nishioka, and M. Farber. (2020) "Trends of publications' citations and altmetrics based on open access types". Proceedings of the ACM/IEEE Joint Conference on Digital Libraries, pp. 503-504.

[37] K. A. Khor, L. G, Yu, A. M. Soehartono. (2021). "Detecting global publication trends in research integrity and research ethics (RIRE) through bibliometrics analysis". *18th International Conference on Scientometrics and Informetrics*, pp. 551-562.

[38] G. J. Hwang, and P. H. Wu. (2012). "Advancements and trends in digital game-based learning research: A review of publications in selected journals from 2001 to 2010". *British Journal of Educational Technology*, vol. 43, no. 1, pp. E6-E10.

[39] M. J. Sousa, and A. Rocha. (2018). "Special section on "emerging trends and challenges in digital learning"". *Universal Access in the Information Society*, vol. 17, no. 4, pp. 675-677.

[40] L. Zhao, C. Cao, Y. Li, Y. Li. (2022). "Determinants of the digital outcome divide in e-learning between rural and urban students: empirical evidence from the covid-19 pandemic based on capital theory". *Computers in Human Behavior*, vol. 130.

[41] M. A. A. Pozin, M. N. M. Nawi, A. Ahmi, A. N. Harun, T. Lapwong. (2019). "Virtual team literature: A bibliometric evaluation". *Test Engineering and Management*, vol. 81, no. 11-12, pp. 3935-3943.

[42] A. Kulakli, and V. Osmanaj. (2020) "Global research on big data in relation with artificial intelligence (A bibliometric study: 2008-2019)". *International Journal of online and biomedical engineering*, vol. 16, no. 2, pp. 31- 46.

[43] J. A, A. Jusoh, N. Idris, A. F. Abbas, A. H. Alsharif. (2021). "Nine years of mobile healthcare research: a bibliometric analysis". *International Journal of online and biomedical engineering*, vol. 17, no.10, pp. 144-159.

[44] D. N. Effendi, Irwandani, W. Anggraini, A. Jatmiko, H. Rahmayanti, I. Z. Ichsan, M. M. Rahman. (2021). "Bibliometric analysis of scientific literacy using VOS viewer: Analysis of science education". *Journal of Physics: Conference Series*, vol. 1796, no.1.

[45] M. Mymoon, S. Mahendran, P. R. Lakhsmi, S. Suryakala. (2016). "Directions in self consolidating concrete research - Mapping using VOS viewer". *Journal of Structural Engineering (India)*, vol. 43, no. 5, pp. 427-435.

[46] B. Jatmiko, T. Sunarti, B. K. Prahani, E. Hariyono, Dwikoranto, F. C. Wibowo, S. Mahtari, M. Asy'Ari. (2021). "Critical thinking skills on physics learning

during covid-19 pandemic: a bibliometric analysis using Vosviewer". *Journal of Physics: Conference Series*, vol. 2110, no.1.

[47] J. L. Anderson and M. Barnett. (2013). "Learning physics with digital game simulations in middle school science". *Journal of Science Education and Technology*, vol. 22, no. 6.

[48] P. Sengupta, K. D. Krinks, D. B. Clark. (2015). "Learning to deflect: conceptual change in physics during digital game play". *Journal of the Learning Sciences*, vol. 24, no. 4, pp. 638-674.

[49] M. Melo. (2018). "The 4C/ID-model in physics education: Instructional design of a digital learning environment to teach electrical circuits". *International Journal of Instruction*,vol. 11, no. 1, pp. 103-122.

[50] E. Euler, C. Prytz, B. Gregorcic. (2020). "Never far from shore: Productive patterns in physics students' use of the digital learning environment Algodoo". *Physics Education*, vol. 55, no. 4.

[51]Sukarno and M.E. Widdah. (2020). "The effect of students' metacognition and digital literacy in virtual lectures during the covid-19 pandemic on achievement in the "methods and strategies on physics learning" course". *Jurnal Pendidikan IPA Indonesia*, vol. 9, no. 4, pp. 477-488.

[52] M. A. Arianto and Y. Basthomi. (2021). "The authors' research gap strategies in elt research article introductions: does Scopus journal quartile matter?". *Journal of Language and Linguistic Studies*, vol. 17, no. 4, pp. 1743-1759.

[53] J. A. Engerman, and R. F. Otto. (2021). "The shift to digital: designing for learning from a culturally relevant interactive media perspective". *Educational Technology Research and Development*, vol. 69, no. 1, pp.301-305.

[54] A. Kashada, H. Li, O. Koshadah. (2020). "Analysis approach to identify factors influence digital learning technology adoption and utilization in developing countries". *International Journal of Emerging Technologies in Learning*, vol. 13, no. 2, pp. 48-59.

[55] R. Nugrahani, W. Wibawanto, R. Nazam, Syakir, Supatmo. (2019). "Augmented interactive wall as a technology-based art learning media". *Journal of Physics: Conference Series,*vol. 1387,no. 1.

[56] R.A. Liliana, W. Raharjo, I. Jauhari. (2020). "The development of interactive learning media with lectora inspire in gas kinetic theory subject to improve the result and students' interest of the eleventh grade students of senior high school". *Journal of Physics: Conference Series*, vol. 1567, no.3.

[57] F. Yang, and W. Wu. (2010) "The application of virtual reality in E-learning". Proceedings of the International Conference on E-Business and E-Government, pp. 5548-5551.

[58] G. Hamed, and A. Aljanazrah. (2020). "The effectiveness of using virtual experiments on students' learning in the general physics lab". *Journal of Information Technology Education: Research*, vol. 19, pp. 977-996.

[59] S. Sujatmika, and W. S. Wibowo. (2020) "Developing d-Worksheets by applying 7 steps of problem-based-learning to enrich students' critical thinking skills". *Journal of Physics: Conference Series*, vol. 1567,no. 4.

[60] M. Balaton, J. Cavadas, P. S. Carvalho, J. J. G. Lima. (2021). "Programming ozobots for teaching astronomy". *Physics Education*, vol. 56, no. 4.

[61] T. Fredlund, J. Airey, C. Linder. (2012). "Exploring the role of physics representations: An illustrative example from students sharing knowledge about refraction". *European Journal of Physics*, vol. 33, no. 3, pp. 657-666.

[62] D. Yang, E. Zargar, A. M. Adams, S. L. Day, C. M. Connor. (2021). "Using interactive e-book user log variables to track reading processes and predict digital learning outcomes". *Assessment for Effective Intervention*, vol. 46, no. 4, pp. 292-303.

[63] L. Roza, Mas'ud, Zulfarina, T. P. Putra. (2021). "Interactive E-module of integrated science with connected type as learning supplement on energy topic". *Journal of Physics: Conference Series*, vol. 2049, no. 1.

[64] J. D. Ametepe, and N. Khan. (2021). "Teaching physics during covid-19 pandemic: Implementation and report of teaching strategies to support student learning". *Physics Education*, vol. 56, no. 6.

[65] N. E. Susilowati, A. Samsudin, Muslim. (2021). "What do physics teachers need? A need analysis of interactive multimedia to train creative thinking in static fluid". *Journal of Physics: Conference Series*, vol. 2098, no. 1.

[66] W. Wongsuwan, J. Huntula, C. C. Liu. (2022). "The interactive computer simulation and learning activity for facilitating students' conceptual understanding on the buoyant force through the CoSci learning platform". *Journal of Physics: Conference Series*, vol. 2145, no. 1.

Commented [U1]: When there are several consecutive citations then write: [1], [2], **Not ([1]-[2], [1-2], [1, 2])**, (**not more than two or three**).

Preferably, all references should be visible in Google Scholar. References should be presented in **a full form** in the same way as they are presented in Google Scholar (APA style).

You have used a large number of references.
You need to reduce this number up to 30-35.
Please delete some of the references that aren't visible in Google Scholar.

We reviewed the first 3 references.
See COMMENTS in attach.
Again check other references you have used.
If they are not visible or are incomplete, you should correct or delete them.

If you are interested, your paper could be published in this issue of the journal (in last week of August, 2022), provided you swiftly respond to the reviewers' remarks.

You should submit us as soon as possible the corrected paper.

Digital Learning Research in The Last 30 Years: Important Role of Interactive Learning in Physics

Binar Kurnia Prahani[1], Mila Candra Pristianti[1], Budi Jatmiko[1], Tan Amelia[2], Firmanul Catur Wibowo[3]

[1]*Universitas Negeri Surabaya, Surabaya, Indonesia*
[2]*Universitas Dinamika,Surabaya, Indonesia*
[3] *Universitas Negeri Jakarta,Jakarta, Indonesia*
binarprahani@unesa.ac.id

***Abstract* – The aim is to analyze top 100 highest citations of digital learning research topic and the important role of interactive learning in physics learning in 1992-2021. This study uses bibliometric analysis and literature review. The trend of digital learning topics is increase steadily, from 2014 to 2021. Digital learning shows an excellent contribution to physics learning. The important role of interactive learning in physics are to improve student learning outcomes, deepen understanding and make learning more interesting. More intensively, further research can be carried out by comparing other learning systems applied in physics learning.**

***Keywords* – Bibliometric, Digital Learning, Education, Physics Learning**

1. Introduction

Various kinds of learning system have been applied according to surrounding conditions, the examples are digital learning. The development of learning systems must pay attention to the ease of adaptation and transformation [1], [2]. Learning development can be done by combining organizational learning theory and general systems theory.

There are many impacts of the covid-19 pandemic, one of which is in the world of education. One of the updates on October 10, 2021, the entire country has reported 219 million cases with 4.55 million deaths [3]. With the danger that threatens, many countries are trying to make learning sustainable [4]. Efforts are made to organize healthy learning during the covid-19 pandemic crisis [5]. The covid-19 outbreak caused the closure of schools and colleges, so that educational institutions designed more flexible. Research conducted by Leonhard [6], Neil [7], and David [8] concluded that during the covid-19 pandemic, student responses showed good acceptance of digital learning. Students accept and adapt easily to digital technology during the covid-19 pandemic.

Physics learning is closely related to natural phenomena and experimental activities. The flexible of physics learning can be done use digital technology or without it [9]. By learning physics through digital learning students are challenged to be more independent, must be easy to adapt and willing to learn. However, there are shortcomings in the implementation of digital learning, namely some places have limited access to digital media, and potential dependence on digital technology [10]. Mentoring and supervision by physics teachers will determine the success of digital learning [11].

From existing studies, there is still no discussion that show the contribution digital learning in physics learning and important role of interactive learning in physics. Some studies tend to discuss digital learning, but to show the right data regarding the analysis, bibliometric studies and literature reviews

Commented [V1]: Write: [1], [2]
Needs a comma and a space.
Check other references you have used.

DOI: 10.18421/TEMxx-xx
https://doi.org/10.18421/TEMxx-xx

Corresponding author: Binar Kurnia Prahani, Universitas Negeri Surabaya, Indonesia

Email: binarprahani@unesa.ac.id

Received: -----.
Accepted: -----.
Published: -----.

are needed. Bibliometric analysis is a method to provide knowledge regarding the growth and flow of literature in a particular publication field [12]. This bibliometric study uses empirical data to track existing publications [13]. This study can analyze the distribution of manuscripts sorted by country, source, year and more [14].

With an explanation of the importance digital learning as well as the existing shortcomings, this research was carried out. The aim is to analyze top 100 highest citations of digital learning research topic, and the important role of interactive learning in physics from 1992 to 2021. For analysis using bibliometrics and also literature review. The objective research include:

1. Analyze the trend of digital learning publications from the last thirty years.
2. Identify the most widely used keywords, the country and author that contribute the most to the publication of digital learning in last thirty years.
3. Identify document types and source titles for digital learning from the last thirty years.
4. Identify the year wise distribution of the top 100 cited digital learning publications from the last thirty years.
5. Identify the contribution digital learning in physics learning over the last thirty years.
6. Identify the advantages and disadvantages of digital learning.
7. Analyze the important role of interactive learning in physics.

2. Methods

This study uses bibliometric analysis and literature review. The data used in this study were taken from Scopus. Scopus is well-known for its largest database of publications in various fields including academics [15], [16]. Data from Scopus can be adjusted according to the needs of the year, title, country, keywords, and so on [17]. In addition, this study uses a literature review from previous studies as a reinforcement of research data.

Research data taken on April 1, 2022. The data in Scopus is selected based on the keywords you want to search for. In this study, the keyword selection stage was carried out twice, the first regarding digital learning. Furthermore, the second keyword are connected with physics learning to find the contribution of digital learning, for more details can be seen in Figure 1. The data obtained in the form of .csv which was then analyzed using Microsoft excel and .ris which was analyzed using VOSViewer [18].

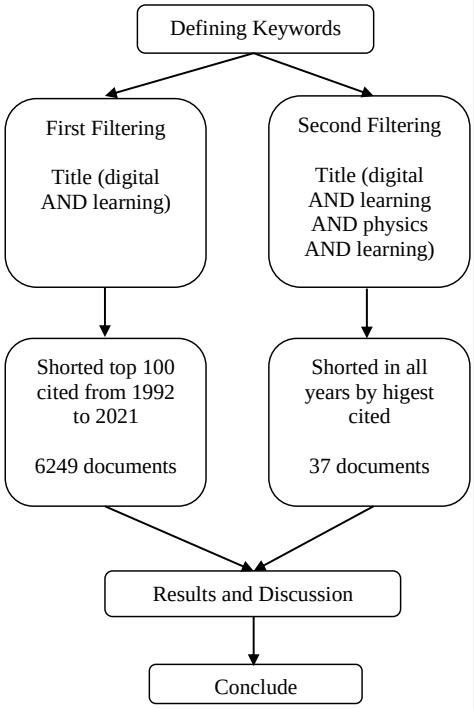

Figure 1. Flowchart for the keyword filtering

3. Results and Discussion

3.1 Publication Trend in Last 30 Years

From Figure 2, we can see the trend of publications related to digital learning. The trend of publication is an important aspect to pay attention to and follow up [19]. Considering that publications must be in accordance with current conditions, which mean the development of a topic is determined from the trend of publications each year [20].

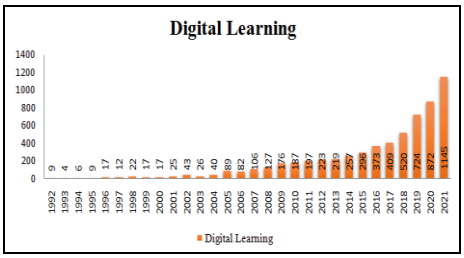

Figure 2. Digital learning publication trends

The highest digital learning publication in 2021 with 1145 documents and the lowest in 1993 with 4 documents. Digital learning publications began to

increase steadily, from 2014 to 2021. The highest increase occurred in 2021 as many as 273 documents from 2020. The researchers tend to be interested in raising the topic of digital learning [21]. This is in line with the fact that the majority of education in the world has used digital learning due to the emergence of the Covid-19 pandemic [22]. So that research related to digital learning has high potential for future research.

3.2 Visualization of The Most Used Keywords, Top Countries and Top Authors Who Contributed the Most

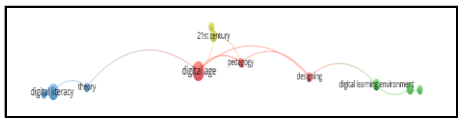

Figure 3. The keywords visualization of digital learning

Figure 3 shows the keyword visualization using VOSViewer. Keywords can describe the subject matter in a publication [23]. For digital learning topics, the most commonly used keyword is "digital age" which has 8 occurrences and "digital literacy" has 6 occurrences.

Table 1. Comparison of the top 10 countries with the most publications in the last thirty years

Top 10 countries	Publications
United States	1,359
United Kingdom	460
China	422
Germany	347
Australia	319
Taiwan	306
Spain	281
Indonesia	221
Canada	208
India	187

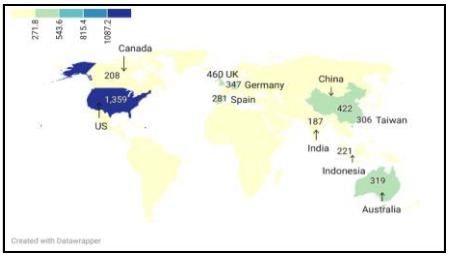

Figure 4. Top 10 Countries with publications about digital learning

From Table 1 and Figure 4, it can be concluded that the United States has the highest contribution over the last thirty years both on the topic of digital learning. There are five countries that consistently occupy the top 10 on all publication topics related to digital learning including the United States, China, United Kingdom, Australia and Spain. To identify the author who has the most publications on each topic of digital learning, using VOS viewer and Microsoft Excel analysis. The results of the Microsoft Excel analysis are shown in Table 2.

Table 2. The top 10 author with the highest citations in the last thirty years

Author	Total Citations	Country
M. Papastergiou	1,880	Greece
K. Kiili	1,978	Findland
C.M. Greenhow	2,509	United States
A.R. Janowczyk	1,269	United States
D.B. Clark	3,069	Canada
A. Madabhushi	14,845*	United States
B. Gros	660	Spain
S. Erhel	429	France
A. Sadik	367	Egypt
B.Q. Huynh	590	United States

Table 2 shows the top 10 authors from the highest citations for the topic of digital learning, M. Papastergiou from Greece. Meanwhile, the highest total citation was owned by A Madabhushi came from the United States. To find out who the author on the topic of digital learning is the most contributing and connected is using VOSViewer. With VOSViewer we can identify the classification of top authors [24]. The grouping and connection of each author is indicated by the presence of clusters [25]. The first result of the digital learning topic is divided into 3 clusters, namely red (n=5), green (4), blue (n=2). H. Beetham is the main author because he has 3 documents with 2 total link strength which is more than any other author.

3.3The Document Types and Source Titles of Top 100 Highest Cited Publication in Last 30 Years

Table 3. The document types of top 100 highest cited digital learning publication in last 30 years

Document Type	Freq-uency	Cited	Mean	Med-ian	SD
Article	81*	14206*	175.3	125	160.8*
Conference paper	7	808	115.4	95	47.2
Review	4	810	202.5*	209.5*	96.6
Note	0	0	0	0	-
Book	7	1011	144.4	129	63.1
Editorial	1	376	376	376	-

Table 3 shows on digital learning topic, the most publications are in the form of articles (n=81). Digital learning has the total cited is 14,206. The standard deviation is quite high, namely digital learning (n=160.8).

Table 4. The source titles of top 100 highest cited publication in last 30 years

Source Title	TD	TC
Computers and Education	13	2983
Educational Technology and Society	4	415
Journal of Computer Assisted Learning	3	565
Journal of Research on Technology in Education	3	530
Language and Learning in the Digital Age	3	468
Geoderma	3	386
ReCALL	3	325
Internet and Higher Education	2	1008
Rethinking Pedagogy for a Digital Age: Designing and Delivering E-Learning	2	343
Learning, Media and Technology	2	264
TD = Total Documents TC = Total Citations		

Table 4 shows the source titles of digital learning are varied. For the highest source title digital learning namely Computers and Education (n=13 documents). The highest total citation is 2,983 namely source title is Computers and Education.

3.4 The Year Wise Distribution of Top 100 Highest Cited Publication in Last 30 Years

Table 5 contains information on the distribution of the top 100 cited publications on the topics of digital learning. The range of data used is from 1992 to 2021.

Table 5. The year wise distribution of top 100 highest cited publication in last 30 years

Year	Citable Year	Digital Learning			
		TC	TD	ACPP	ACPPY
1992	30	0	0	0	0
1993	29	0	0	0	0
1994	28	0	0	0	0
1995	27	215	2	107.5	3.9
1996	26	0	0	0	0
1997	25	0	0	0	0
1998	24	0	0	0	0
1999	23	0	0	0	0
2000	22	0	0	0	0
2001	21	420	2	210	10
2002	20	0	0	0	0
2003	19	0	0	0	0
2004	18	454	2	227	12.6
2005	17	1237	4	309.2*	18.2
2006	16	270	2	135	8.4
2007	15	891	5	178.2	11.8
2008	14	869	5	173.8	12.4
2009	13	2282	7	326	25.1
2010	12	421	3	140.3	11.6
2011	11	932	7	133.1	12.1
2012	10	1327	10	132.7	13.3
2013	9	1199	7	171.3	19
2014	8	894	8	111.7	13.9
2015	7	443	4	110.7	15.8
2016	6	2699*	11*	245.4	40.9
2017	5	567	4	141.7	28.4
2018	4	881	6	146.8	36.7
2019	3	884	9	98.2	32.7
2020	2	326	2	163	81.5*
2021	1	0	0	0	0
*The Highest Number					

This information can be used to see in what year the top 100 cited publications were produced on the topic. From this study it was found that the highest year is 2016 (n=11 documents). In addition, from this study it was found that the highest year is 2016 (n=2,699 citations). The highest average citation per paper per year in 2020 is 81,5.

3.5Literature Review of Digital Learning to Physics Learning

Table 6 contains the results of the literature review by taking into account the quartiles, citations, and findings to provide recommendations regarding the selected paper.

Table 6. Top 5 highest cited paper showed contribution of digital learning to physics learning

Author	SJR	Citation	Findings
Anderson, J. L., & Barnett, M. [26]	1,03 (Q1)	46	Digital learning with game simulations has a positive impact on the learning outcomes of junior high school students in physics learning.
Sengupta, P., Krinks, K. D., & Clark, D. B. [27]	4,06 (Q1)	22	The results of the study show that the combination of using digital learning fosters student physics learning motivation
Melo, M. [28]	0,54 (Q2)	4	The use of digital learning 4C/ID model in physics content to students has a positive impact on learning outcomes.
Euler, E., Prytz, C., & Gregorcic, B. [29]	0,34 (Q3)	1	Digital learning using the Algodoo application gives students the opportunity to explore physics learning materials for free and able to attract students' attention in learning
Sukarno & Widdah, M.E. [30]	0,49 (Q2)	1	Students' metacognitive and digital literacy skills increase in physics learning.

The ranking system of reputable journals based on the subject or category of the related journal field is

also called quartiles [31]. From these results, it can be seen that the topic of digital learning has the highest citation is 46, thus, research related to digital learning in physics will have a lot of potentials, and its novelty will be quite high. Digital learning tends to take advantage of interactive learning applications to increase student motivation and learning outcomes [32].

3.6 Advantage and Disadvantage of Digital Learning to Physics Learning

Table 7. Discussion about digital learning

Discussion	Digital Learning
Meaning	Learning media that can be done digitally without having to wait for internet access to start.
Characteristics	• Some digital learning can be accessed without internet • Not tied to face-to-face or non-face-to-face learning • More towards the learning media
Advantage	Can be used in various places, can trigger students to think creatively and innovatively
Disadvantage	Can lead to dependence on digital tools so that it can cause laziness in students

Table 7 broadly speaking, it can be concluded that digital learning has advantages in flexibility and types of media that utilize sophisticated digital tools. While the disadvantages have an impact on students' lifestyles which can become dependent on digital learning media. The digital learning is a learning process that requires internet access, while digital learning does not always require internet access.

3.7 Analyze the Important Role of Interactive Learning in Physics Based on Digital Learning Research

Learning physics still tends to be difficult for most students to understand. Physics learning needs to be set more interactively for students. The use of interactive learning media can be integrated using a combination of video, graphics, text, and sound. Digital learning by applying interactive virtual reality can deepen students' understanding of physics material. In addition, through good quality worksheets in digital learning can improve students' critical thinking skills in learning physics. Practical activities can play an important role in engaging students with the world of science, especially when using digital tools. So, it can be concluded that interactive learning can improve student learning outcomes [33].

The majority of students in the 21st century is proficient in advanced technology and are adaptable. For example, the use of interactive modules is also very important to apply because, according to research [34], digital learning of physics with interactive modules shows compatibility and a positive impact. Since the last three years, the world has been affected by the pandemic, so academic units must also think about effective learning methods that can still improve student achievement. Therefore, interactive learning in physics is starting to be more widely applied. One of them is by using interactive multimedia, which is able to improve students' understanding of concepts [35]. Interactive learning plays an important role in deepening the concept of physics and making the learning atmosphere more interesting even though digital learning.

4. Conclusion

Research results analysis using bibliometric studies and literature reviews related to digital learning research get several conclusions. The conclusion is that the trend of digital learning topics is increase steadily, from 2014 to 2021. The most commonly used keywords are digital age, and digital literacy. United States (US) has made the highest contribution over the last thirty years on digital learning. The author with the highest citation on digital learning is M. Papastergiou from Greece. The type of document that is often published in the article. The highest source titles digital learning, namely Computers and Education. The highest average citation per paper per year is in 2020 where digital learning (n=81,5). The digital learning topic contribute to learning physics. From explanation above, the future research related to digital learning in physics will have a lot of potentials, and its novelty will be quite high. The important role of interactive learning in physics is to improve student learning outcomes, train critical thinking skills, deepen understanding of concepts and make learning more interesting. The advantages in flexibility and types of media that utilize sophisticated digital tools. While the disadvantages have an impact on students' lifestyles which can become dependent on digital learning media and because it’s using the internet network, which requires costs and a strong signal because not all areas have a strong network connection.

The implication of this research is to show the trend of publication of digital learning topics so that future researchers can show more benefits related to these topics. With this article, researchers can find out the strengths and weaknesses of digital learning topic and can find updates for future research. The limitation of the study is that some research results at Scopus are limited to full access. More intensively, further research can be carried out by comparing other learning systems applied in physics learning.

5. Acknowledgement

The author's gratitude goes to the *Direktora tJenderal Pendidikan Tinggi, Riset, dan Teknologi; Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, Indonesia* who has supported funding in *Penelitian Dasar Unggulan Perguruan Tinggi* - DRTPM 2022 [Contract Number: 29551/UN38.9/LK.04.00/2022].

References

[1] Dias Canedo E., Aymoré Martins V., Coelho Ribeiro V., dos Reis V.E., Carvalho Chaves L.A., Machado Gravina R., Alberto Moreira Dias F., Lopes de Mendonça F.L., Orozco A.L.S., Balaniuk R., de Sousa R.T Jr. (2021). Development and Evaluation of an Intelligence and Learning System in Jurisprudence Text Mining in the Field of Competition Defense. *Applied Sciences*, 11(23), 11365.

[2] Hsu, F. H., Lin, I. H., Yeh, H. C., & Chen, N. S. (2022). Effect of Socratic Reflection Prompts via video-based learning system on elementary school students' critical thinking skills. *Computers & Education*, *183*, 104497.

[3] Taimoor, H. (2022). A global update on covid-19 pandemic: Vaccines and new variants. *Pakistan Journal of Medicine & Dentistry*, 11(1), 89-93.

[4] Donham, C., Barron, H. A., Alkhouri, J. S., Kumarath, M. C., Alejandro, W., Menke, E., & Kranzfelder, P. (2022). I will teach you here or there, I will try to teach you anywhere: perceived supports and barriers for emergency remote teaching during the COVID-19 pandemic. *International Journal of STEM Education*, 9(19), 1-25.

[5] Temelli, D. (2022). Reflexes of international organizations regarding education in the covid-19 pandemic process and comparing implementations in turkey. *Milli Egitim*, 51(233), 887-909.

[7] Olmes, G. L., Zimmermann, J. S. M., Stotz, L., Takacs, F. Z., Hamza, A., Radosa, M. P., Findeklee, S., Solomayer, E. F., & Radosa, J. C. (2021). Students' attitudes toward digital learning during the covid-19 pandemic: a survey conducted following an online course in gynecology and obstetrics. *Archives of Gynecology and Obstetrics*, 304(4), 957-963.

[8] Guppy, N., Verpoorten, D., Boud, D., Lin, L., Tai. J., & Bartolic, S. (2022). The post-COVID-19 future of digital learning in higher education: Views from educators, students, and other professionals in six countries. *British Journal of Educational Technology*, 1(1), 1-22.

[9] Adde, D., Amponsah, S., & Gborti, B. J. (2022). Covid-19 pandemic and the shift to digital learning: experiences of students in a community college in ghana. *Community College Journal of Research and Practice*, 46(1), 101-112.

[10] Poluakan, C., & Katuuk, D. (2021). PIMCA: a new alternativesto physics learning model. *Journal of Physics: Conference Series*, 2165, 1-6.

[11] Ivanec, T. P. (2022). The lack of academic social interactions and students' learning difficulties during covid-19 faculty lockdowns in Croatia: the mediating role of the perceived sense of life disruption caused by the pandemic and the adjustment to online studying. *Journal Social Science*, 11(42), 1-11.

[12] Vieyra, R., & Himmelsbach, J. (2022). Teachers' disciplinary boundedness in the implementation of integrated computational modeling in physics. *Journal of Science Education and Technology*, 31(2), 153-165.

[13] Dewantara, D., Sofianto, E. W. N., Misbah, & Munawaroh, D. (2021). Physics e-module: A review and bibliometric analysis. *Journal of Physics: Conference Series*, 2104, 1-7.

[14] 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), 136-154.

[15] Wang, J., Shen, L., & Zhou, W. (2021). A bibliometric analysis of quantum computing literature: mapping and evidences from Scopus. *Technology Analysis and Strategic Management*, 33(11), 1347-1363.

[16] Kamaruzzaman, W. M., Nasir, N., Hamidi, N. A., Yusof, N., Shaifudin, M. S., Suhaimi, A. M. A. A. M., Badruddin, M. A., Adnan, A., Nik, W. M. N. W., & Ghazali, M. S. M. (2022). 25 years of progress on plants as corrosion inhibitors through a bibliometric analysis using the Scopus database (1995–2020). *Arabian Journal of Chemistry*, 15(4), 4-19.

[17] Kulkanjanapiban, P., & Silwattananusarn T. (2022). Comparative analysis of Dimensions and Scopus bibliographic data sources: An approach to university research productivity. *International Journal of Electrical and Computer Engineering*, 12(1) 706-720.

[18] Putri, C. R., Soleh, S. M., Saregar, A., Anugrah, A., & Susilowati, N. E. (2021). Bibliometric analysis: Augmented reality-based physics laboratory with VOSviewer software. *Journal of Physics: Conference Series*, 1796, 1-12.

[19] Nishioka, C., & Farber, M. (2020). Trends of publications' citations and altmetrics based on open access types. Proceedings of the ACM/IEEE Joint Conference on Digital Libraries, 503-504.

[20] Soehartono, A. M., Yu, L. G., & Khor, K. A. (2021). Detecting global publication trends in research integrity and research ethics (RIRE) through bibliometrics analysis. *18th International Conference on Scientometrics and Informetrics*, 551-562.

[21] Sousa, M. J., & Rocha, A. (2018). Special section on "emerging trends and challenges in digital learning". *Universal Access in the Information Society*, 17(4), 675-677.

[22] Zhao, L., Cao, C., Li, Y., & Li, Y. (2022). Determinants of the digital outcome divide in e-learning between rural and urban students: empirical evidence from the covid-19 pandemic based on capital theory. *Computers in Human Behavior*, 130(1), 1-15.

[23] 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 and biomedical engineering*, 17(10), 144-159.

[24] Effendi, D. N., Irwandani, Anggraini, W., Jatmiko, A., Rahmayanti, H., Ichsan, I. Z., & Rahman, M. M. (2021). Bibliometric analysis of scientific literacy using VOS viewer: Analysis of science education. *Journal of Physics: Conference Series*, 1796, 1-10.

[25] Pristianti, M. C. (2022). Top 100 cited research of confirmatory factor analysis (CFA) in education from 2012 to 2021. *International Journal of Current Educational Research*, 1(1), 68-83.

[26] Anderson, J. L., & Barnett, M. (2013). Learning physics with digital game simulations in middle school science. *Journal of Science Education and Technology*, 22(6), 914-926.

[27] Sengupta, P., Krinks, K. D., & Clark, D. B. (2015). Learning to deflect: conceptual change in physics during digital gameplay. *Journal of the Learning Sciences*, 24(4), 638-674.

[28] Melo M. (2018). The 4C/ID-model in physics education: Instructional design of a digital learning environment to teach electrical circuits. *International Journal of Instruction*, 11(1), 103-122.

[29] Euler, E., Prytz, C., & Gregorcic, B. (2020). Never far from shore: Productive patterns in physics students' use of the digital learning environment Algodoo. *Physics Education*, 55(4), 1-8.

[30] Sukarno & Widdah, M.E. (2020). The effect of students' metacognition and digital literacy in virtual lectures during the covid-19 pandemic on achievement in the "methods and strategies on physics learning" course. *Jurnal Pendidikan IPA Indonesia*, 9(4), 477-488.

[31] Arianto, M. A. & Basthomi, Y. (2021). The authors' research gap strategies in elt research article introductions: does Scopus journal quartile matter?. *Journal of Language and Linguistic Studies*, 17(4), 1743-1759.

[32] Engerman, J. A., & Otto, R. F. (2021). The shift to digital: designing for learning from a culturally relevant interactive media perspective. *Educational Technology Research and Development*, 69(1), 301-305.

[33] Balaton, M., Cavadas, J., Carvalho, P. S., & Lima, J. J. G. (2021). Programming ozobots for teaching astronomy. *Physics Education*, 56(4), 1-8.

[34] Wongsuwan, W., Huntula, J., & Liu, C. C. (2022). The interactive computer simulation and learning activity for facilitating students' conceptual understanding on the buoyant force through the CoSci learning platform. *Journal of Physics: Conference Series*, 2145, 1-6.

[35] Susilowati, N. E., Samsudin, A., & Muslim. (2021). What do physics teachers need? A need analysis of interactive multimedia to train creative thinking in static fluid. *Journal of Physics: Conference Series*, 2098, 1-6.

Digital Learning Research in The Last 30 Years: Important Role of Interactive Learning in Physics

Binar Kurnia Prahani[1], Mila Candra Pristianti[1], Budi Jatmiko[1], Tan Amelia[2], Firmanul Catur Wibowo[3]

[1]*Universitas Negeri Surabaya, Surabaya, Indonesia*
[2]*Universitas Dinamika,Surabaya, Indonesia*
[3] *Universitas Negeri Jakarta,Jakarta, Indonesia*
binarprahani@unesa.ac.id

***Abstract* – The aim is to analyze top 100 highest citations of digital learning research topic and the important role of interactive learning in physics learning in 1992-2021. This study uses bibliometric analysis and literature review. The trend of digital learning topics is increase steadily, from 2014 to 2021. Digital learning shows an excellent contribution to physics learning. The important role of interactive learning in physics are to improve student learning outcomes, deepen understanding and make learning more interesting. More intensively, further research can be carried out by comparing other learning systems applied in physics learning.**

***Keywords* – Bibliometric, Digital Learning, Education, Physics Learning**

1. Introduction

Various kinds of learning system have been applied according to surrounding conditions, the examples are digital learning. The development of learning systems must pay attention to the ease of adaptation and transformation [1],[2]. Learning development can be done by combining organizational learning theory and general systems theory.

There are many impacts of the covid-19 pandemic, one of which is in the world of education. One of the updates on October 10, 2021, the entire country has reported 219 million cases with 4.55 million deaths [3]. With the danger that threatens, many countries are trying to make learning sustainable [4]. Efforts are made to organize healthy learning during the covid-19 pandemic crisis [5]. The covid-19 outbreak caused the closure of schools and colleges, so that educational institutions designed more flexible. Research conducted by Leonhard [6], Neil [7], and David [8] concluded that during the covid-19 pandemic, student responses showed good acceptance of digital learning. Students accept and adapt easily to digital technology during the covid-19 pandemic.

Physics learning is closely related to natural phenomena and experimental activities. The flexible of physics learning can be done use digital technology or without it [9]. By learning physics through digital learning students are challenged to be more independent, must be easy to adapt and willing to learn. However, there are shortcomings in the implementation of digital learning, namely some places have limited access to digital media, and potential dependence on digital technology [10]. Mentoring and supervision by physics teachers will determine the success of digital learning [11].

From existing studies, there is still no discussion that show the contribution digital learning in physics learning and important role of interactive learning in physics. Some studies tend to discuss digital learning, but to show the right data regarding the analysis, bibliometric studies and literature reviews

Commented [V1]: Write: [1], [2]
Needs a comma and a space.
Check other references you have used.

DOI: 10.18421/TEMxx-xx
https://doi.org/10.18421/TEMxx-xx

Corresponding author: Binar Kurnia Prahani, Universitas Negeri Surabaya, Indonesia

Email: binarprahani@unesa.ac.id

Received: -----.
Accepted: -----.
Published: -----.

are needed. Bibliometric analysis is a method to provide knowledge regarding the growth and flow of literature in a particular publication field [12]. This bibliometric study uses empirical data to track existing publications [13]. This study can analyze the distribution of manuscripts sorted by country, source, year and more [14].

With an explanation of the importance digital learning as well as the existing shortcomings, this research was carried out. The aim is to analyze top 100 highest citations of digital learning research topic, and the important role of interactive learning in physics from 1992 to 2021. For analysis using bibliometrics and also literature review. The objective research include:

1. Analyze the trend of digital learning publications from the last thirty years.
2. Identify the most widely used keywords, the country and author that contribute the most to the publication of digital learning in last thirty years.
3. Identify document types and source titles for digital learning from the last thirty years.
4. Identify the year wise distribution of the top 100 cited digital learning publications from the last thirty years.
5. Identify the contribution digital learning in physics learning over the last thirty years.
6. Identify the advantages and disadvantages of digital learning.
7. Analyze the important role of interactive learning in physics.

2. Methods

This study uses bibliometric analysis and literature review. The data used in this study were taken from Scopus. Scopus is well-known for its largest database of publications in various fields including academics [15],[16]. Data from Scopus can be adjusted according to the needs of the year, title, country, keywords, and so on [17]. In addition, this study uses a literature review from previous studies as a reinforcement of research data.

Research data taken on April 1, 2022. The data in Scopus is selected based on the keywords you want to search for. In this study, the keyword selection stage was carried out twice, the first regarding digital learning. Furthermore, the second keyword are connected with physics learning to find the contribution of digital learning. The data obtained in the form of .csv which was then analyzed using microsoft excel and .ris which was analyzed using VOSviewer [18].

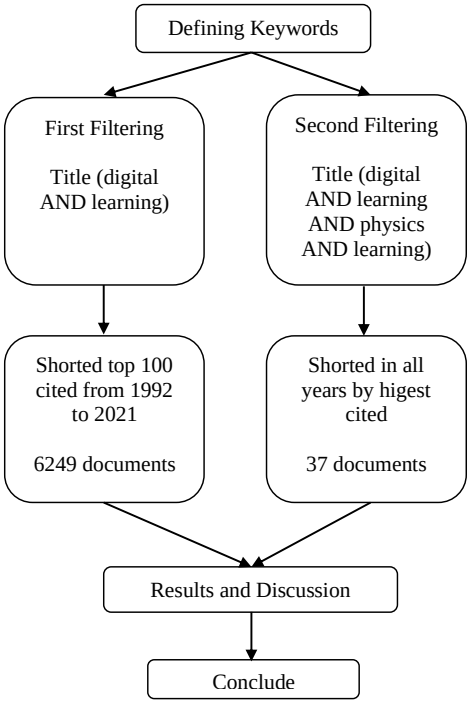

Figure 1. Flowchart for the keyword filtering

Commented [V2]:
You did not enter a label Figure 1 in the text.

3. Results and Discussion

3.1 Publication Trend in Last 30 Years

From Figure 2, we can see the trend of publications related to digital learning. The trend of publication is an important aspect to pay attention to and follow up [19]. Considering that publications must be in accordance with current conditions, which mean the development of a topic is determined from the trend of publications each year [20].

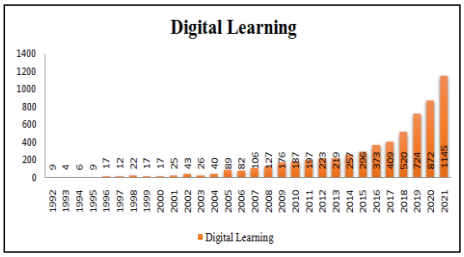

Figure 2. Digital learning publication trends

The highest digital learning publication in 2021 with 1145 documents and the lowest in 1993 with 4

documents. Digital learning publications began to increase steadily, from 2014 to 2021. The highest increase occurred in 2021 as many as 273 documents from 2020. The researchers tend to be interested in raising the topic of digital learning [21]. This is in line with the fact that the majority of education in the world has used digital learning due to the emergence of the Covid-19 pandemic [22]. So that research related to digital learning has high potential for future research.

3.2 Visualization of The Most Used Keywords, Top Countries and Top Authors Who Contributed The Most

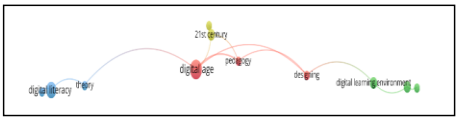

Figure 3. The keywords visualization of digital learning

Figure 3 shows the keyword visualization using VOSviewer. Keywords can describe the subject matter in a publication [23]. For digital learning topics, the most commonly used keyword is "digital age" which has 8 occurrences and "digital literacy" has 6 occurrences.

Table 1. *Comparison of the top 10 countries with the most publications in the last thirty years*

Top 10 countries	Publications
United States	1,359
United Kingdom	460
China	422
Germany	347
Australia	319
Taiwan	306
Spain	281
Indonesia	221
Canada	208
India	187

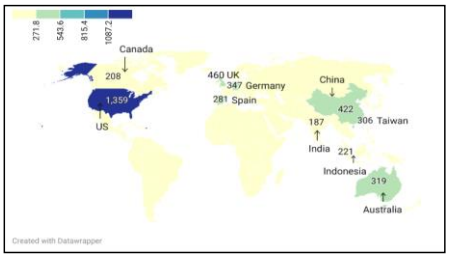

Figure 4. *Top 10 Countries with publications about digital learning*

From Table 1 and Figure 4, it can be concluded that the United States has the highest contribution over the last thirty years both on the topic of digital learning. There are five countries that consistently occupy the top 10 on all publication topics related to digital learning including the United States, China, United Kingdom, Australia and Spain.To identify the author who has the most publications on each topic of digital learning, using VOS viewer and Microsoft Excel analysis. The results of the Microsoft Excel analysis are shown in Table 2.

Table 2. *The top 10 author with the highest citations in the last thirty years*

Author	Total Citations	Country
M. Papastergiou	1,880	Greece
K. Kiili	1,978	Findland
C.M. Greenhow	2,509	United States
A.R. Janowczyk	1,269	United States
D.B. Clark	3,069	Canada
A. Madabhushi	14,845*	United States
B. Gros	660	Spain
S. Erhel	429	France
A. Sadik	367	Egypt
B.Q. Huynh	590	United States

Table 2 shows the top 10 authors from the highest citations for the topic of digital learning, M. Papastergiou from Greece. Meanwhile, the highest total citation was owned by A Madabhushi came from the United States. To find out who the author on the topic of digital learning is the most contributing and connected is using VOSViewer. With VOSViewer we can identify the classification of top authors [24]. The grouping and connection of each author is indicated by the presence of clusters [25]. The first result of the digital learning topic is divided into 3 clusters, namely red (n=5), green (4), blue (n=2). H. Beetham is the main author because he has 3 documents with 2 total link strength which is more than any other author.

3.3The Document Types and Source Titles of Top 100 Highest Cited Publication in Last 30 Years

Table 3. *The document types of top 100 highest cited digital learning publication in last 30 years*

Document Type	Freq-uency	Cited	Mean	Med-ian	SD
Article	81*	14206*	175.3	125	160.8*
Conference paper	7	808	115.4	95	47.2
Review	4	810	202.5*	209.5*	96.6
Note	0	0	0	0	-
Book	7	1011	144.4	129	63.1
Editorial	1	376	376	376	-

Table 3 shows on digital learning topic, the most publications are in the form of articles (n=81). Digital learning has the total cited is 14,206. The standard deviation is quite high, namely digital learning (n=160.8).

Table 4. *The source titles of top 100 highest cited publication in last 30 years*

Source Title	TD	TC
Computers and Education	13	2983
Educational Technology and Society	4	415
Journal of Computer Assisted Learning	3	565
Journal of Research on Technology in Education	3	530
Language and Learning in the Digital Age	3	468
Geoderma	3	386
ReCALL	3	325
Internet and Higher Education	2	1008
Rethinking Pedagogy for a Digital Age: Designing and Delivering E-Learning	2	343
Learning, Media and Technology	2	264
TD = Total Documents TC = Total Citations		

Table 4 shows the source titles of digital learning are varied. For the highest source title digital learning namely Computers and Education (n=13 documents). The highest total citation is 2,983 namely source title is Computers and Education.

3.4 The Year Wise Distribution of Top 100 Highest Cited Publication in Last 30 Years

Table 5 contains information on the distribution of the top 100 cited publications on the topics of digital learning. The range of data used is from 1992 to 2021.

Table 5. *The year wise distribution of top 100 highest cited publication in last 30 years*

Year	Citable Year	Digital Learning			
		TC	TD	ACPP	ACPPY
1992	30	0	0	0	0
1993	29	0	0	0	0
1994	28	0	0	0	0
1995	27	215	2	107.5	3.9
1996	26	0	0	0	0
1997	25	0	0	0	0
1998	24	0	0	0	0
1999	23	0	0	0	0
2000	22	0	0	0	0
2001	21	420	2	210	10
2002	20	0	0	0	0
2003	19	0	0	0	0
2004	18	454	2	227	12.6
2005	17	1237	4	309.2*	18.2
2006	16	270	2	135	8.4
2007	15	891	5	178.2	11.8
2008	14	869	5	173.8	12.4
2009	13	2282	7	326	25.1
2010	12	421	3	140.3	11.6
2011	11	932	7	133.1	12.1
2012	10	1327	10	132.7	13.3
2013	9	1199	7	171.3	19
2014	8	894	8	111.7	13.9
2015	7	443	4	110.7	15.8
2016	6	2699*	11*	245.4	40.9
2017	5	567	4	141.7	28.4
2018	4	881	6	146.8	36.7
2019	3	884	9	98.2	32.7
2020	2	326	2	163	81.5*
2021	1	0	0	0	0
*The Highest Number					

This information can be used to see in what year the top 100 cited publications were produced on the topic. From this study it was found that the highest year is 2016 (n=11 documents). In addition, from this study it was found that the highest year is 2016 (n=2,699 citations). The highest average citation per paper per year in 2020 is 81,5.

3.5Literature Review of Digital Learning to Physics Learning

Table 6 contains the results of the literature review by taking into account the quartiles, citations, and findings to provide recommendations regarding the selected paper.

Table 6. *Top 5 highest cited paper showed contribution of digital learning to physics learning*

Author	SJR	Citation	Findings
Anderson, J. L., & Barnett, M. [26]	1,03 (Q1)	46	Digital learning with game simulations has a positive impact on the learning outcomes of junior high school students in physics learning.
Sengupta, P., Krinks, K. D., & Clark, D. B. [27]	4,06 (Q1)	22	The results of the study show that the combination of using digital learning fosters student physics learning motivation
Melo, M. [28]	0,54 (Q2)	4	The use of digital learning 4C/ID model in physics content to students has a positive impact on learning outcomes.
Euler, E., Prytz, C., & Gregorcic, B. [29]	0,34 (Q3)	1	Digital learning using the Algodoo application gives students the opportunity to explore physics learning materials for free and able to attract students' attention in learning
Sukarno & Widdah, M.E. [30]	0,49 (Q2)	1	Students' metacognitive and digital literacy skills increase in physics learning.

The ranking system of reputable journals based on the subject or category of the related journal field is also called quartiles [31]. From these results, it can be seen that the topic of digital learning has the highest citation is 46, thus, research related to digital learning in physics will have a lot of potentials, and its novelty will be quite high. Digital learning tends to take advantage of interactive learning applications to increase student motivation and learning outcomes [32].

3.6 Advantage and Disadvantage of Digital Learning to Physics Learning

Table 7. *Discussion about digital learning*

Discussion	Digital Learning
Meaning	Learning media that can be done digitally without having to wait for internet access to start.
Characteristics	• Some digital learning can be accessed without internet • Not tied to face-to-face or non-face-to-face learning • More towards the learning media
Advantage	Can be used in various places, can trigger students to think creatively and innovatively
Disadvantage	Can lead to dependence on digital tools so that it can cause laziness in students

Broadly speaking, it can be concluded that digital learning has advantages in flexibility and types of media that utilize sophisticated digital tools. While the disadvantages have an impact on students' lifestyles which can become dependent on digital learning media. The digital learning is a learning process that requires internet access, while digital learning does not always require internet access.

3.7 Analyze the Important Role of Interactive Learning in Physics Based on Digital Learning Research

Learning physics still tends to be difficult for most students to understand. Physics learning needs to be set more interactively for students. The use of interactive learning media can be integrated using a combination of video, graphics, text, and sound. Digital learning by applying interactive virtual reality can deepen students' understanding of physics material. In addition, through good quality worksheets in digital learning can improve students' critical thinking skills in learning physics. Practical activities can play an important role in engaging students with the world of science, especially when using digital tools. So, it can be concluded that interactive learning can improve student learning outcomes [33].

The majority of students in the 21st century are proficient in advanced technology and are adaptable. For example, the use of interactive modules is also very important to apply because, according to research [34], digital learning of physics with interactive modules shows compatibility and a positive impact. Since the last three years, the world has been affected by the pandemic, so academic units must also think about effective learning methods that can still improve student achievement. Therefore, interactive learning in physics is starting to be more widely applied. One of them is by using interactive multimedia, which is able to improve students' understanding of concepts [35]. Interactive learning plays an important role in deepening the concept of physics and making the learning atmosphere more interesting even though digital learning.

Commented [V3]:
You did not enter a label Table 7 in the text.

4. Conclusion

Research results analysis using bibliometric studies and literature reviews related to digital learning research get several conclusions. The conclusion is that the trend of digital learning topics is increase steadily, from 2014 to 2021. The most commonly used keywords are digital age, and digital literacy. United States (US) has made the highest contribution over the last thirty years on digital learning. The author with the highest citation on digital learning is M. Papastergiou from Greece. The type of document that is often published in the article. The highest source titles digital learning, namely Computers and Education. The highest average citation per paper per year is in 2020 where digital learning (n=81,5). The digital learning topic contribute to learning physics. From explanation above, the future research related to digital learning in physics will have a lot of potentials, and its novelty will be quite high. The important role of interactive learning in physics is to improve student learning outcomes, train critical thinking skills, deepen understanding of concepts and make learning more interesting. The advantages in flexibility and types of media that utilize sophisticated digital tools. While the disadvantages have an impact on students' lifestyles which can become dependent on digital learning media and because it's using the internet network, which requires costs and a strong signal because not all areas have a strong network connection.

The implication of this research is to show the trend of publication of digital learning topics so that future researchers can show more benefits related to these topics. With this article, researchers can find out the strengths and weaknesses of digital learning topic and can find updates for future research. The limitation of the study is that some research results at Scopus are limited to full access. More intensively,

further research can be carried out by comparing other learning systems applied in physics learning.

5. Acknowledgement

The author's gratitude goes to the *Direktora tJenderal Pendidikan Tinggi, Riset, dan Teknologi; Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, Indonesia* who has supported funding in *Penelitian Dasar Unggulan Perguruan Tinggi* - DRTPM 2022 [Contract Number: 29551/UN38.9/LK.04.00/2022].

References

[1] Canedo, E. D., Martins, V. A., Ribeiro, V. C., Dos, R. V. E., Chaves, L. A. C., Gravina, R. M., Dias, F. A. M., Mendonca, F. L. L., Orozco, A. L. S., Balaniuk, R., & De, S. R. (2021). Development and evaluation of an intelligence and learning system in jurisprudence text mining in the field of competition defense. *Applied Science Switzerland*, 11(23), 1-24.

[2] Hsu, F. H., Lin, I. H., Yeh, H. C., & Chen, N. S. (2022). Effect of Socratic reflection prompts via video-based learning system on elementary school students' critical thinking skills. *Computers and Education*,183(1), 1-15.

[3] Taimoor, H. (2022). A global update on covid-19 pandemic: Vaccines and new variants. *Pakistan Journal of Medicine & Dentistry*, 11(1), 89-93.

[4] Donham, C., Barron, H. A., Alkhouri, J. S., Kumarath, M. C., Alejandro, W., Menke, E., & Kranzfelder, P. (2022). I will teach you here or there, I will try to teach you anywhere: perceived supports and barriers for emergency remote teaching during the COVID-19 pandemic. *International Journal of STEM Education*, 9(19), 1-25.

[5] Temelli, D. (2022). Reflexes of international organizations regarding education in the covid-19 pandemic process and comparing implementations in turkey. *Milli Egitim*, 51(233), 887-909.

[7] Olmes, G. L., Zimmermann, J. S. M., Stotz, L., Takacs, F. Z., Hamza, A., Radosa, M. P., Findeklee, S., Solomayer, E. F., & Radosa, J. C. (2021). Students' attitudes toward digital learning during the covid-19 pandemic: a survey conducted following an online course in gynecology and obstetrics. *Archives of Gynecology and Obstetrics*, 304(4), 957-963.

[8] Guppy, N., Verpoorten, D., Boud, D., Lin, L., Tai. J., & Bartolic, S. (2022). The post-COVID-19 future of digital learning in higher education: Views from educators, students, and other professionals in six countries. *British Journal of Educational Technology*, 1(1), 1-22.

[9] Adde, D., Amponsah, S., & Gborti, B. J. (2022). Covid-19 pandemic and the shift to digital learning: experiences of students in a community college in ghana. *Community College Journal of Research and Practice*, 46(1), 101-112.

[10] Poluakan, C., & Katuuk, D. (2021). PIMCA: a new alternativesto physics learning model. *Journal of Physics: Conference Series*, 2165(1), 1-6.

[11] Ivanec, T. P. (2022). The lack of academic social interactions and students' learning difficulties during covid-19 faculty lockdowns in Croatia: the mediating role of the perceived sense of life disruption caused by the pandemic and the adjustment to online studying. *Journal Social Science*, 11(42), 1-11.

[12] Vieyra, R., & Himmelsbach, J. (2022). Teachers' disciplinary boundedness in the implementation of integrated computational modeling in physics. *Journal of Science Education and Technology*, 31(2), 153-165.

[13] Dewantara, D., Sofianto, E. W. N., Misbah, & Munawaroh, D. (2021). Physics e-module: A review and bibliometric analysis. *Journal of Physics: Conference Series*, 2104(1), 1-7.

[14] 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), 136-154.

[15] Wang, J., Shen, L., & Zhou, W. (2021). A bibliometric analysis of quantum computing literature: mapping and evidences from Scopus. *Technology Analysis and Strategic Management*, 33(11), 1347-1363.

[16] Kamaruzzaman, W. M. I. W. M., Nasir, N. A. M., Hamidi, N. A. S. M., Yusof, N., Shaifudin, M. S., Suhaimi, A. M. A. A. M., Badruddin, M. A., Adnan, A., Nik, W. M. N. W., & Ghazali, M. S. M. (2022). 25 years of progress on plants as corrosion inhibitors through a bibliometric analysis using the Scopus database (1995–2020). *Arabian Journal of Chemistry*, 15(4), 4-19.

[17] Kulkanjanapiban, P., & Silwattananusarn T. (2022). Comparative analysis of Dimensions and Scopus bibliographic data sources: An approach to university research productivity. *International Journal of Electrical and Computer Engineering*, 12(1) 706-720.

[18] Putri, C. R., Soleh, S. M., Saregar, A., Anugrah, A., & Susilowati, N. E. (2021). Bibliometric analysis: Augmented reality-based physics laboratory with VOSviewer software. *Journal of Physics: Conference Series*, 1796(1), 1-12.

[19] Nishioka, C., & Farber, M. (2020). Trends of publications' citations and altmetrics based on open access types. Proceedings of the ACM/IEEE Joint Conference on Digital Libraries, 503-504.

[20] Soehartono, A. M., Yu, L. G., & Khor, K. A. (2021). Detecting global publication trends in research integrity and research ethics (RIRE) through bibliometrics analysis. *18th International Conference on Scientometrics and Informetrics*, 551-562.

[21] Sousa, M. J., & Rocha, A. (2018). Special section on "emerging trends and challenges in digital learning". *Universal Access in the Information Society*, 17(4), 675-677.

[22] Zhao, L., Cao, C., Li, Y., & Li, Y. (2022). Determinants of the digital outcome divide in e-learning between rural and urban students: empirical evidence from the covid-19 pandemic based on

Commented [V4]:
Reference is not visible.
Reference is not in the Google Scholar.
It cannot be found on the Internet in this form.

Commented [V5]: Full form in the Google Scholar:

Hsu, F. H., Lin, I. H., Yeh, H. C., & Chen, N. S. (2022). Effect of Socratic Reflection Prompts via video-based learning system on elementary school students' critical thinking skills. *Computers & Education*, *183*, 104497.

capital theory. *Computers in Human Behavior*, 130(1), 1-15.
[23] 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 and biomedical engineering*, 17(10), 144-159.
[24] Effendi, D. N., Irwandani, Anggraini, W., Jatmiko, A., Rahmayanti, H., Ichsan, I. Z., & Rahman, M. M. (2021). Bibliometric analysis of scientific literacy using VOS viewer: Analysis of science education. *Journal of Physics: Conference Series*, 1796(1), 1-10.
[25] Pristianti, M. C. (2022). Top 100 cited research of confirmatory factor analysis (CFA) in education from 2012 to 2021. *International Journal of Current Educational Research*, 1(1), 68-83.
[26] Anderson, J. L., & Barnett, M. (2013). Learning physics with digital game simulations in middle school science. *Journal of Science Education and Technology*, 22(6), 914-926.
[27] Sengupta, P., Krinks, K. D., & Clark, D. B. (2015). Learning to deflect: conceptual change in physics during digital gameplay. *Journal of the Learning Sciences*, 24(4), 638-674.
[28] Melo M. (2018). The 4C/ID-model in physics education: Instructional design of a digital learning environment to teach electrical circuits. *International Journal of Instruction*, 11(1), 103-122.
[29] Euler, E., Prytz, C., & Gregorcic, B. (2020). Never far from shore: Productive patterns in physics students' use of the digital learning environment Algodoo. *Physics Education*, 55(4), 1-8.
[30] Sukarno & Widdah, M.E. (2020). The effect of students' metacognition and digital literacy in virtual lectures during the covid-19 pandemic on achievement in the "methods and strategies on physics learning" course. *Jurnal Pendidikan IPA Indonesia*, 9(4), 477-488.
[31] Arianto, M. A. & Basthomi, Y. (2021). The authors' research gap strategies in elt research article introductions: does Scopus journal quartile matter?. *Journal of Language and Linguistic Studies*, 17(4), 1743-1759.
[32] Engerman, J. A., & Otto, R. F. (2021). The shift to digital: designing for learning from a culturally relevant interactive media perspective. *Educational Technology Research and Development*, 69(1), 301-305.
[33] Balaton, M., Cavadas, J., Carvalho, P. S., & Lima, J. J. G. (2021). Programming ozobots for teaching astronomy. *Physics Education*, 56(4), 1-8.
[34] Wongsuwan, W., Huntula, J., & Liu, C. C. (2022). The interactive computer simulation and learning activity for facilitating students' conceptual understanding on the buoyant force through the CoSci learning platform. *Journal of Physics: Conference Series*, 2145(1), 1-6.
[35] Susilowati, N. E., Samsudin, A., & Muslim. (2021). What do physics teachers need? A need analysis of interactive multimedia to train creative thinking in static fluid. *Journal of Physics: Conference Series*, 2098(1), 1-6.

Editor:
Preferably, all references should be visible in Google Scholar.
References should be presented in **a full form** in the same way as they are presented in Google Scholar (APA style).

Rearrange references in APA style, for example:
[1]. Hemmasian Kashania M.M., & Dobregob K.V. (2013). Heat and mass transfer in natural draft cooling towers, *Journal of Engineering Physics and Thermophysics*, 86(5), 1072-1082.

We reviewed a few references.
Again check other references you have used.
If they are not visible or are incomplete, you should correct or delete them.
Reviewer asked for you to correct text indicated in the COMMENTS.

After the corrections you should send us your paper again as soon as possible.

Digital Learning Research in The Last 30 Years: Important Role of Interactive Learning in Physics

Binar Kurnia Prahani[1], Mila Candra Pristianti[1], Budi Jatmiko[1], Tan Amelia[2], Firmanul Catur Wibowo[3]

[1]*Universitas Negeri Surabaya, Surabaya, Indonesia*
[2]*Universitas Dinamika,Surabaya, Indonesia*
[3] *Universitas Negeri Jakarta,Jakarta, Indonesia*
binarprahani@unesa.ac.id

***Abstract* – The aim is to analyze top 100 highest citations of digital learning research topic and the important role of interactive learning in physics learning in 1992-2021. This study uses bibliometric analysis and literature review. The trend of digital learning topics is increase steadily, from 2014 to 2021. Digital learning shows an excellent contribution to physics learning. The important role of interactive learning in physics are to improve student learning outcomes, deepen understanding and make learning more interesting. More intensively, further research can be carried out by comparing other learning systems applied in physics learning.**

***Keywords* – Bibliometric, Digital Learning, Education, Physics Learning**

1. Introduction

Various kinds of learning system have been applied according to surrounding conditions, the examples are digital learning. The development of learning systems must pay attention to the ease of adaptation and transformation [1], [2]. Learning development can be done by combining organizational learning theory and general systems theory.

There are many impacts of the covid-19 pandemic, one of which is in the world of education. One of the updates on October 10, 2021, the entire country has reported 219 million cases with 4.55 million deaths [3]. With the danger that threatens, many countries are trying to make learning sustainable [4]. Efforts are made to organize healthy learning during the covid-19 pandemic crisis [5]. The covid-19 outbreak caused the closure of schools and colleges, so that educational institutions designed more flexible. Research conducted by Leonhard [6], Neil [7], and David [8] concluded that during the covid-19 pandemic, student responses showed good acceptance of digital learning. Students accept and adapt easily to digital echnology during the covid-19 pandemic.

Physics learning is closely related to natural phenomena and experimental activities. The flexible of physics learning can be done use digital technology or without it [9]. By learning physics through digital learning students are challenged to be more independent, must be easy to adapt and willing to learn. However, there are shortcomings in the implementation of digital learning, namely some places have limited access to digital media, and potential dependence on digital technology [10]. Mentoring and supervision by physics teachers will determine the success of digital learning [11].

From existing studies, there is still no discussion that show the contribution digital learning in physics learning and important role of interactive learning in physics. Some studies tend to discuss digital learning, but to show the right data regarding the analysis, bibliometric studies and literature reviews

DOI: 10.18421/TEMxx-xx
https://doi.org/10.18421/TEMxx-xx

Corresponding author: Binar Kurnia Prahani, Universitas Negeri Surabaya, Indonesia

Email: binarprahani@unesa.ac.id

Received: -----.
Accepted: -----.
Published: -----.

are needed. Bibliometric analysis is a method to provide knowledge regarding the growth and flow of literature in a particular publication field [12]. This bibliometric study uses empirical data to track existing publications [13]. This study can analyze the distribution of manuscripts sorted by country, source, year and more [14].

With an explanation of the importance digital learning as well as the existing shortcomings, this research was carried out. The aim is to analyze top 100 highest citations of digital learning research topic, and the important role of interactive learning in physics from 1992 to 2021. For analysis using bibliometrics and also literature review. The objective research include:

1. Analyze the trend of digital learning publications from the last thirty years.
2. Identify the most widely used keywords, the country and author that contribute the most to the publication of digital learning in last thirty years.
3. Identify document types and source titles for digital learning from the last thirty years.
4. Identify the year wise distribution of the top 100 cited digital learning publications from the last thirty years.
5. Identify the contribution digital learning in physics learning over the last thirty years.
6. Identify the advantages and disadvantages of digital learning.
7. Analyze the important role of interactive learning in physics.

2. Methods

This study uses bibliometric analysis and literature review. The data used in this study were taken from Scopus. Scopus is well-known for its largest database of publications in various fields including academics [15], [16]. Data from Scopus can be adjusted according to the needs of the year, title, country, keywords, and so on [17]. In addition, this study uses a literature review from previous studies as a reinforcement of research data.

Research data taken on April 1, 2022. The data in Scopus is selected based on the keywords you want to search for. In this study, the keyword selection stage was carried out twice, the first regarding digital learning. Furthermore, the second keyword are connected with physics learning to find the contribution of digital learning, for more details can be seen in Figure 1. The data obtained in the form of .csv which was then analyzed using Microsoft excel and.ris which was analyzed using VOSViewer [18].

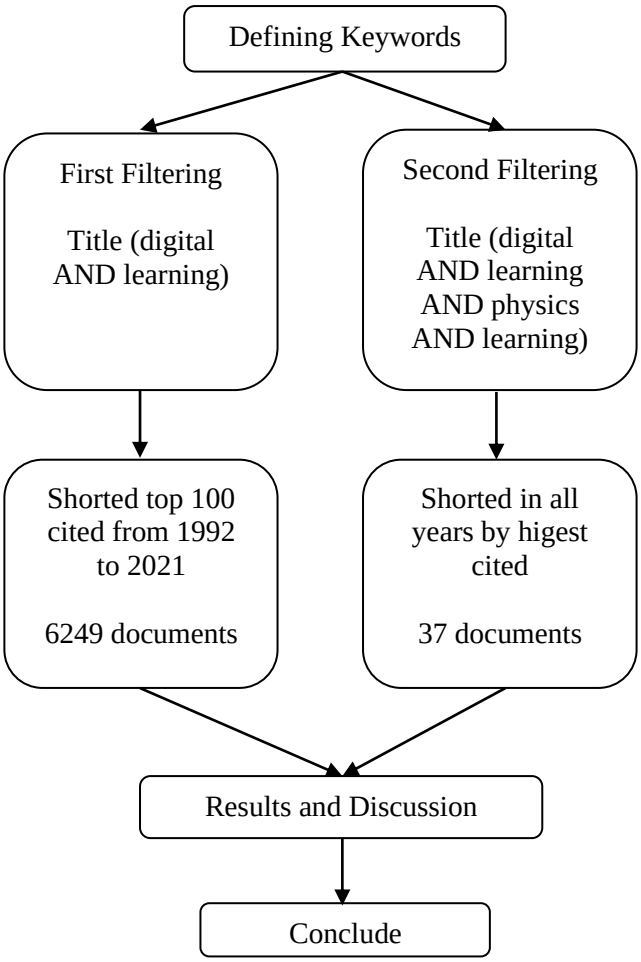

Figure 1. Flowchart for the keyword filtering

3. Results and Discussion

3.1 Publication Trend in Last 30 Years

From Figure 2, we can see the trend of publications related to digital learning. The trend of publication is an important aspect to pay attention to and follow up [19]. Considering that publications must be in accordance with current conditions, which mean the development of a topic is determined from the trend of publications each year [20].

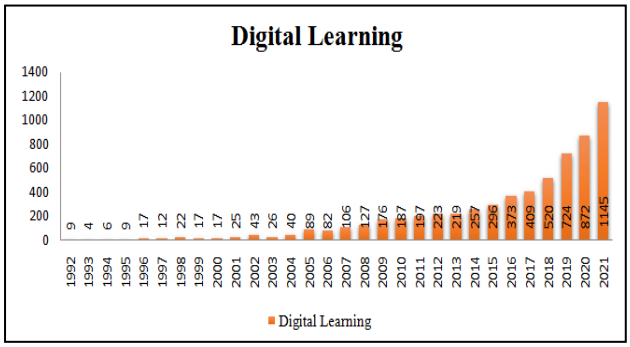

Figure 2. Digital learning publication trends

The highest digital learning publication in 2021 with 1145 documents and the lowest in 1993 with 4 documents. Digital learning publications began to

increase steadily, from 2014 to 2021. The highest increase occurred in 2021 as many as 273 documents from 2020. The researchers tend to be interested in raising the topic of digital learning [21]. This is in line with the fact that the majority of education in the world has used digital learning due to the emergence of the Covid-19 pandemic [22]. So that research related to digital learning has high potential for future research.

3.2 Visualization of The Most Used Keywords, Top Countries and Top Authors Who Contributed the Most

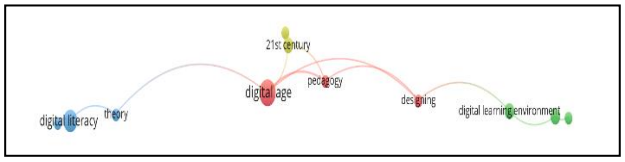

Figure 3. The keywords visualization of digital learning

Figure 3shows the keyword visualization using VOSViewer. Keywords can describe the subject matter in a publication [23]. For digital learning topics, the most commonly used keyword is "digital age" which has 8 occurrences and "digital literacy" has 6occurrences.

Table 1. Comparison of the top 10 countries with the most publications in the last thirty years

Top 10 countries	Publications
United States	1,359
United Kingdom	460
China	422
Germany	347
Australia	319
Taiwan	306
Spain	281
Indonesia	221
Canada	208
India	187

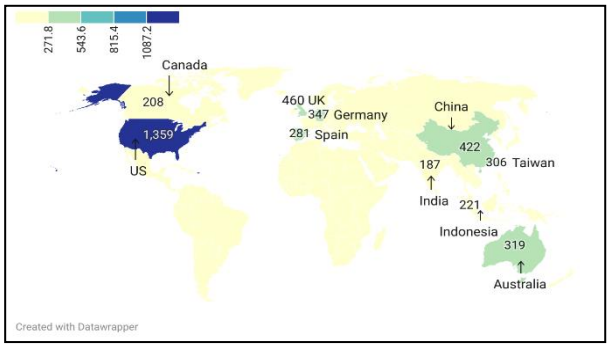

Figure 4.Top 10 Countries with publications about digital learning

From Table 1 and Figure 4, it can be concluded that the United States has the highest contribution over the last thirty years both on the topic of digital learning. There are five countries that consistently occupy the top 10 on all publication topics related to digital learning including the United States, China, United Kingdom, Australia and Spain. To identify the author who has the most publications on each topic of digital learning, using VOS viewer and Microsoft Excel analysis. The results of the Microsoft Excel analysis are shown in Table 2.

Table 2. The top 10 author with the highest citations in the last thirty years

Author	Total Citations	Country
M. Papastergiou	1,880	Greece
K. Kiili	1,978	Findland
C.M. Greenhow	2,509	United States
A.R. Janowczyk	1,269	United States
D.B. Clark	3,069	Canada
A. Madabhushi	14,845*	United States
B. Gros	660	Spain
S. Erhel	429	France
A. Sadik	367	Egypt
B.Q. Huynh	590	United States

Table 2 shows the top 10 authors from the highest citations for the topic of digital learning, M. Papastergiou from Greece. Meanwhile, the highest total citation was owned by A Madabhushi came from the United States.To find out who the author on the topic of digital learning is the most contributing and connected is using VOSViewer. With VOSViewer we can identify the classification of top authors [24]. The grouping and connection of each author is indicated by the presence of clusters [25]. The first result of the digital learning topic is divided into 3 clusters, namely red (n=5), green (4), blue (n=2). H. Beetham is the main author because he has 3 documents with 2 total link strength which is more than any other author.

3.3 The Document Types and Source Titles of Top 100 Highest Cited Publication in Last 30 Years

Table 3. The document types of top 100 highest cited digital learning publication in last 30 years

Document Type	Freq-uency	Cited	Mean	Med-ian	SD
Article	81*	14206*	175.3	125	160.8*
Conference paper	7	808	115.4	95	47.2
Review	4	810	202.5*	209.5*	96.6
Note	0	0	0	0	-
Book	7	1011	144.4	129	63.1
Editorial	1	376	376	376	-

Table 3 shows on digital learning topic, the most publications are in the form of articles (n=81). Digital learning has the total cited is 14,206. The standard deviation is quite high, namely digital learning (n=160.8).

Table 4. The source titles of top 100 highest cited publication in last 30 years

Source Title	TD	TC
Computers and Education	13	2983
Educational Technology and Society	4	415
Journal of Computer Assisted Learning	3	565
Journal of Research on Technology in Education	3	530
Language and Learning in the Digital Age	3	468
Geoderma	3	386
ReCALL	3	325
Internet and Higher Education	2	1008
Rethinking Pedagogy for a Digital Age: Designing and Delivering E-Learning	2	343
Learning, Media and Technology	2	264
TD = Total Documents TC = Total Citations		

Table 4 shows the source titles of digital learning are varied. For the highest source title digital learning namely Computers and Education (n=13 documents). The highest total citation is 2,983 namely source title is Computers and Education.

3.4 The Year Wise Distribution of Top 100 Highest Cited Publication in Last 30 Years

Table 5 contains information on the distribution of the top 100 cited publications on the topics of digital learning. The range of data used is from 1992 to 2021.

Table 5. The year wise distribution of top 100 highest cited publication in last 30 years

Year	Citable Year	Digital Learning			
		TC	TD	ACPP	ACPPY
1992	30	0	0	0	0
1993	29	0	0	0	0
1994	28	0	0	0	0
1995	27	215	2	107.5	3.9
1996	26	0	0	0	0
1997	25	0	0	0	0
1998	24	0	0	0	0
1999	23	0	0	0	0
2000	22	0	0	0	0
2001	21	420	2	210	10
2002	20	0	0	0	0
2003	19	0	0	0	0
2004	18	454	2	227	12.6
2005	17	1237	4	309.2*	18.2
2006	16	270	2	135	8.4
2007	15	891	5	178.2	11.8
2008	14	869	5	173.8	12.4
2009	13	2282	7	326	25.1
2010	12	421	3	140.3	11.6
2011	11	932	7	133.1	12.1
2012	10	1327	10	132.7	13.3
2013	9	1199	7	171.3	19
2014	8	894	8	111.7	13.9
2015	7	443	4	110.7	15.8
2016	6	2699*	11*	245.4	40.9
2017	5	567	4	141.7	28.4
2018	4	881	6	146.8	36.7
2019	3	884	9	98.2	32.7
2020	2	326	2	163	81.5*
2021	1	0	0	0	0
*The Highest Number					

This information can be used to see in what year the top 100 cited publications were produced on the topic. From this study it was found that the highest year is 2016 (n=11 documents). In addition, from this study it was found that the highest year is 2016 (n=2,699 citations). The highest average citation per paper per year in 2020 is 81,5.

3.5 Literature Review of Digital Learning to Physics Learning

Table 6contains the results of the literature review by taking into account the quartiles, citations, and findings to provide recommendations regarding the selected paper.

Table 6. Top 5 highest cited paper showed contribution of digital learning to physics learning

Author	SJR	Citation	Findings
Anderson, J. L., & Barnett, M. [26]	1,03 (Q1)	46	Digital learning with game simulations has a positive impact on the learning outcomes of junior high school students in physics learning.
Sengupta, P., Krinks, K. D., & Clark, D. B. [27]	4,06 (Q1)	22	The results of the study show that the combination of using digital learning fosters student physics learning motivation
Melo, M. [28]	0,54 (Q2)	4	The use of digital learning 4C/ID model in physics content to students has a positive impact on learning outcomes.
Euler, E., Prytz, C., & Gregorcic, B. [29]	0,34 (Q3)	1	Digital learning using the Algodoo application gives students the opportunity to explore physics learning materials for free and able to attract students' attention in learning
Sukarno & Widdah, M.E. [30]	0,49 (Q2)	1	Students' metacognitive and digital literacy skills increase in physics learning.

The ranking system of reputable journals based on the subject or category of the related journal field is

also called quartiles [31]. From these results, it can be seen that the topic of digital learning has the highest citation is 46, thus, research related to digital learning in physics will have a lot of potentials, and its novelty will be quite high. Digital learning tends to take advantage of interactive learning applications to increase student motivation and learning outcomes [32].

3.6 Advantage and Disadvantage of Digital Learning to Physics Learning

Table 7. Discussion about digital learning

Discussion	Digital Learning
Meaning	Learning media that can be done digitally without having to wait for internet access to start.
Characteristics	• Some digital learning can be accessed without internet • Not tied to face-to-face or non-face-to-face learning • More towards the learning media
Advantage	Can be used in various places, can trigger students to think creatively and innovatively
Disadvantage	Can lead to dependence on digital tools so that it can cause laziness in students

Table 7 broadly speaking, it can be concluded that digital learning has advantages in flexibility and types of media that utilize sophisticated digital tools. While the disadvantages have an impact on students' lifestyles which can become dependent on digital learning media. The digital learning is a learning process that requires internet access, while digital learning does not always require internet access.

3.7 Analyze the Important Role of Interactive Learning in Physics Based on Digital Learning Research

Learning physics still tends to be difficult for most students to understand. Physics learning needs to be set more interactively for students. The use of interactive learning media can be integrated using a combination of video, graphics, text, and sound. Digital learning by applying interactive virtual reality can deepen students' understanding of physics material. In addition, through good quality worksheets in digital learning can improve students' critical thinking skills in learning physics. Practical activities can play an important role in engaging students with the world of science, especially when using digital tools. So, it can be concluded that interactive learning can improve student learning outcomes [33].

The majority of students in the 21st century is proficient in advanced technology and are adaptable. For example, the use of interactive modules is also very important to apply because, according to research [34], digital learning of physics with interactive modules shows compatibility and a positive impact. Since the last three years, the world has been affected by the pandemic, so academic units must also think about effective learning methods that can still improve student achievement. Therefore, interactive learning in physics is starting to be more widely applied. One of them is by using interactive multimedia, which is able to improve students' understanding of concepts [35]. Interactive learning plays an important role in deepening the concept of physics and making the learning atmosphere more interesting even though digital learning.

4. Conclusion

Research results analysis using bibliometric studies and literature reviews related to digital learning research get several conclusions. The conclusion is that the trend of digital learning topics is increase steadily, from 2014 to 2021. The most commonly used keywords are digital age, and digital literacy. United States (US) has made the highest contribution over the last thirty years on digital learning. The author with the highest citation on digital learning is M. Papastergiou from Greece. The type of document that is often published in the article. The highest source titles digital learning, namely Computers and Education. The highest average citation per paper per year is in 2020 where digital learning (n=81,5). The digital learning topic contribute to learning physics. From explanation above, the future research related to digital learning in physics will have a lot of potentials, and its novelty will be quite high. The important role of interactive learning in physics is to improve student learning outcomes, train critical thinking skills, deepen understanding of concepts and make learning more interesting. The advantages in flexibility and types of media that utilize sophisticated digital tools. While the disadvantages have an impact on students' lifestyles which can become dependent on digital learning media and because it’s using the internet network, which requires costs and a strong signal because not all areas have a strong network connection.

The implication of this research is to show the trend of publication of digital learning topics so that future researchers can show more benefits related to these topics. With this article, researchers can find out the strengths and weaknesses of digital learning topic and can find updates for future research. The limitation of the study is that some research results at Scopus are limited to full access. More intensively, further research can be carried out by comparing other learning systems applied in physics learning.

5. Acknowledgement

The author's gratitude goes to the *Direktorat Jenderal Pendidikan Tinggi, Riset, dan Teknologi; Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, Indonesia* who has supported funding in *Penelitian Dasar Unggulan Perguruan Tinggi* - DRTPM 2022 [Contract Number: 29551/UN38.9/LK.04.00/2022].

References

[1]Dias Canedo E., Aymoré Martins V., Coelho Ribeiro V., dos Reis V.E., Carvalho Chaves L.A., Machado Gravina R., Alberto Moreira Dias F., Lopes de Mendonça F.L., Orozco A.L.S., Balaniuk R., de Sousa R.T Jr. (2021). Development and Evaluation of an Intelligence and Learning System in Jurisprudence Text Mining in the Field of Competition Defense. *Applied Sciences*, 11(23), 11365. https://doi.org/10.3390/app112311365

[2] Hsu, F. H., Lin, I. H., Yeh, H. C., & Chen, N. S. (2022). Effect of Socratic Reflection Prompts via video-based learning system on elementary school students' critical thinking skills. *Computers & Education*, *183*, 104497. https://doi.org/10.1016/j.compedu.2022.104497

[3] Hassan, T. (2022). A global update on covid-19 pandemic: Vaccines and new variants. *Pakistan Journal of Medicine & Dentistry*, 11(1), 89-93. https://doi.org/10.36283/PJMD11-1/015

[4] Donham, C., Barron, H. A., Alkhouri,J. S., Kumarath, M. C., Alejandro, W., Menke, E., & Kranzfelder, P. (2022). I will teach you here or there, I will try to teach you anywhere: perceived supports and barriers for emergency remote teaching during the COVID-19 pandemic. *International Journal of STEM Education*, 9(19), 1-25. https://doi.org/10.1186/s40594-022-00341-3

[5] Temelli, D. (2022). Reflexes of international organizations regarding education in the covid-19 pandemic process and comparing implementations in turkey. *Milli Egitim*, 51(233), 887-909. https://doi.org/10.37669/milliegitim.788444

[7] Olmes, G. L., Zimmermann, J. S. M., Stotz, L., Takacs, F. Z., Hamza, A., Radosa, M. P., Findeklee, S., Solomayer, E. F.,&Radosa, J. C. (2021). Students' attitudes toward digital learning during the covid-19 pandemic: a survey conducted following an online course in gynecology and obstetrics. *Archives of Gynecology and Obstetrics*, 304(4), 957-963. https://doi.org/10.1007/s00404-021-06131-6

[8] Guppy, N., Verpoorten, D., Boud, D., Lin, L., Tai. J., & Bartolic, S. (2022). The post-COVID-19 future of digital learning in higher education: Views from educators, students, and other professionals in six countries. *British Journal of Educational Technology*, 1(1), 1-22. https://doi.org/10.1111/bjet.13212

[9] Adde, D., Amponsah, S., & Gborti, B. J. (2022). Covid-19 pandemic and the shift to digital learning: experiences of students in a community college in ghana. *Community College Journal of Research and Practice*, 46(1), 101-112. https://doi.org/10.1080/10668926.2021.1972364

[10] Poluakan, C., & Katuuk, D. (2021). PIMCA: a new alternativesto physics learning model. *Journal of Physics: Conference Series*, 2165, 1-6. https://doi.org/10.1088/1742-6596/2165/1/012013

[11] Ivanec, T. P. (2022). The lack of academic social interactions and students' learning difficulties during covid-19 faculty lockdowns in Croatia: the mediating role of the perceived sense of life disruption caused by the pandemic and the adjustment to online studying. *Journal Social Science*, 11(42), 1-11. https://doi.org/10.3390/socsci11020042

[12] Vieyra, R., & Himmelsbach, J. (2022). Teachers' disciplinary boundedness in the implementation of integrated computational modeling in physics. *Journal of Science Education and Technology*, 31(2), 153-165. https://doi.org/10.1007/s10956-021-09938-9

[13] Dewantara, D., Sofianto, E. W. N., Misbah, &Munawaroh, D. (2021). Physics e-module: A review and bibliometric analysis. *Journal of Physics: Conference Series*, 2104, 1-7. https://doi.org/10.1088/1742-6596/2104/1/012008

[14] 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), 136-154. https://doi.org/10.3991/ijim.v15i08.20415

[15] Wang, J., Shen, L.,& Zhou, W. (2021). A bibliometric analysis of quantum computing literature: mapping and evidences from Scopus.*Technology Analysis and Strategic Management*, 33(11), 1347-1363. https://doi.org/10.1080/09537325.2021.1963429

[16] Kamaruzzaman, W. M., Nasir, N., Hamidi, N. A., Yusof, N., Shaifudin, M. S., Suhaimi, A. M. A. A. M., Badruddin, M. A., Adnan, A., Nik, W. M. N. W., & Ghazali, M. S. M. (2022). 25 years of progress on plants as corrosion inhibitors through a bibliometric analysis using the Scopus database (1995–2020). *Arabian Journal of Chemistry*, 15(4), 4-19. https://doi.org/10.1016/j.arabjc.2021.103655

[17] Kulkanjanapiban, P., & Silwattananusarn T. (2022). Comparative analysis of Dimensions and Scopus bibliographic data sources: An approach to university research productivity. *International Journal of Electrical and Computer Engineering*, 12(1) 706-720. https://doi.org/10.11591/ijece.v12i1.pp706-720

[18] Putri, C. R., Soleh, S. M., Saregar, A., Anugrah, A.,&Susilowati, N. E. (2021). Bibliometric analysis: Augmented reality-based physics laboratory with VOSviewer software. *Journal of Physics: Conference Series*, 1796, 1-12. https://doi.org/10.1088/1742-6596/1796/1/012056

[19] Nishioka, C., & Farber, M. (2020). Trends of publications' citations and altmetrics based on open access types. Proceedings of the ACM/IEEE Joint Conference on Digital Libraries, 503-504. https://doi.org/10.1145/3383583.3398584

[20] Soehartono, A. M., Yu, L. G., & Khor, K. A. (2021). Detecting global publication trends in research integrity and research ethics (RIRE) through bibliometrics analysis. *18th International Conference on Scientometrics and Informetrics*, 551-562. https://doi.org/10.1007/s11192-022-04400-y

[21] Sousa, M. J., & Rocha, A. (2018). Special section on "emerging trends and challenges in digital learning". *Universal Access in the Information Society*, 17(4), 675-677. https://doi.org/10.1007/s10209-017-0572-6

[22] Zhao, L., Cao, C., Li, Y., & Li, Y. (2022). Determinants of the digital outcome divide in e-learning between rural and urban students: empirical evidence from the covid-19 pandemic based on capital theory. *Computers in Human Behavior*,130(1), 1-15. https://doi.org/10.1016/j.chb.2021.107177

[23] 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 and biomedical engineering*, 17(10), 144-159. https://doi.org/10.3991/ijoe.v17i10.25243

[24] Effendi, D. N., Irwandani, Anggraini, W., Jatmiko, A., Rahmayanti, H., Ichsan, I. Z., & Rahman, M. M. (2021). Bibliometric analysis of scientific literacy using VOS viewer: Analysis of science education. *Journal of Physics: Conference Series*, 1796, 1-10. https://doi.org/10.1088/1742-6596/1796/1/012096

[25] Pristianti, M. C. (2022). Top 100 cited research of confirmatory factor analysis (CFA) in education from 2012 to 2021. *International Journal of Current Educational Research*, 1(1), 68-83. https://doi.org/10.53621/ijocer.v1i1.140

[26] Anderson, J. L., & Barnett, M. (2013). Learning physics with digital game simulations in middle school science. *Journal of Science Education and Technology*, 22(6), 914-926. https://doi.org/10.1007/s10956-013-9438-8

[27] Sengupta, P., Krinks, K. D., & Clark, D. B. (2015). Learning to deflect: conceptual change in physics during digital gameplay. *Journal of the Learning Sciences*, 24(4), 638-674. http://dx.doi.org/10.1080/10508406.2015.1082912

[28] Melo M. (2018). The 4C/ID-model in physics education: Instructional design of a digital learning environment to teach electrical circuits. *International Journal of Instruction*, 11(1), 103-122. https://doi.org/10.12973/iji.2018.1118a

[29] Euler, E., Prytz, C., & Gregorcic, B. (2020). Never far from shore: Productive patterns in physics students' use of the digital learning environment Algodoo. *Physics Education*, 55(4), 1-8. https://doi.org/10.1088/1361-6552/ab83e7

[30] Sukarno & Widdah, M.E. (2020). The effect of students' metacognition and digital literacy in virtual lectures during the covid-19 pandemic on achievement in the "methods and strategies on physics learning" course. *Jurnal Pendidikan IPA Indonesia*, 9(4), 477-488. https://doi.org/10.15294/jpii.v9i4.25332

[31] Arianto, M. A. & Basthomi, Y. (2021). The authors' research gap strategies in elt research article introductions: does Scopus journal quartile matter?. *Journal of Language and Linguistic Studies*, 17(4), 1743-1759. https://doi.org/10.52462/jlls.127

[32] Engerman, J. A., & Otto, R. F. (2021). The shift to digital: designing for learning from a culturally relevant interactive media perspective. *Educational Technology Research and Development*, 69(1), 301-305. https://doi.org/10.1007/s11423-020-09889-9

[33] Balaton, M., Cavadas, J., Carvalho, P. S., & Lima, J. J. G. (2021). Programming ozobots for teaching astronomy. *Physics Education*, 56(4), 1-8. https://doi.org/10.1088/1361-6552/abfb44

[34] Wongsuwan, W., Huntula, J., &Liu, C. C. (2022). The interactive computer simulation and learning activity for facilitating students' conceptual understanding on the buoyant force through the CoSci learning platform. *Journal of Physics: Conference Series*, 2145, 1-6. https://doi.org/10.1088/1742-6596/2145/1/012075

[35] Susilowati, N. E., Samsudin, A., & Muslim. (2021). What do physics teachers need? A need analysis of interactive multimedia to train creative thinking in static fluid. *Journal of Physics: Conference Series*, 2098, 1-6. https://doi.org/10.1088/1742-6596/2098/1/012029

Digital Learning Research in the Last 30 Years: Important Role of Interactive Learning in Physics

Binar Kurnia Prahani[1], Mila Candra Pristianti[1], Budi Jatmiko[1], Tan Amelia[2], Firmanul Catur Wibowo[3]

[1]*Universitas Negeri Surabaya, Surabaya, Indonesia*
[2]*Universitas Dinamika,Surabaya, Indonesia*
[3] *Universitas Negeri Jakarta,Jakarta, Indonesia*
binarprahani@unesa.ac.id

***Abstract* – The aim is to analyze top 100 highest citations of digital learning research topics and the important role of interactive learning in physics in 1992-2021. This study uses bibliometric analysis and literature review. The trend of digital learning topics is increasing steadily, from 2014 to 2021. Digital learning shows an excellent contribution to physics learning. The important role of interactive learning in physics is to improve student learning outcomes, deepen understanding and make learning more interesting. More intensively, further research can be carried out by comparing other learning systems applied in physics learning.**

***Keywords* – bibliometric, digital learning, education, physics learning**

1. Introduction

Various kinds of learning systems have been applied according to surrounding conditions, the example is digital learning. The development of learning systems must pay attention to the ease of adaptation and transformation [1], [2]. Learning development can be done by combining organizational learning theory and general systems theory.

There are many impacts of the covid-19 pandemic, one of which is in the world of education. One of the updates from the covid-19 case on October 10, 2021, all countries have reported 219 million positive cases of covid-19 with 4.55 million deaths [3]. With the danger that threatens, many countries are trying to make learning sustainable [4]. Efforts are made to organize healthy learning during the covid-19 pandemic crisis [5]. The covid-19 outbreak has led to the closure of schools and colleges, so educational institutions are designed to be more flexible, namely the learning process can be carried out even though it is not face-to-face, reducing learning hours and utilizing digital platforms. Research conducted by Leonhard [6], Neil [7], and David [8] concluded that during the covid-19 pandemic, student responses showed good acceptance of digital learning. Students accepted and adapted easily to digital technology during the covid-19 pandemic.

Physics learning is closely related to natural phenomena and experimental activities. The flexibility of physics learning can be done using digital technology or without it [9]. By learning physics through digital learning students are challenged to be more independent, must easily adapt and be willing to learn. However, there are shortcomings in the implementation of digital learning, namely some places have limited access to digital media and potential dependence on digital technology [10]. Mentoring and supervision by physics teachers will determine the success of digital learning [11].

DOI: 10.18421/TEMxx-xx
https://doi.org/10.18421/TEMxx-xx

Corresponding author: Binar Kurnia Prahani, Universitas Negeri Surabaya, Indonesia

Email: binarprahani@unesa.ac.id

Received: -----.
Accepted: -----.
Published: -----.

From the existing studies, there is still no discussion that shows the contribution of digital learning in physics learning and the important role of interactive learning in physics. Some studies tend to discuss digital learning, but to show the right data regarding the analysis, bibliometric studies and literature reviews are needed. Bibliometric analysis is a method to provide knowledge regarding the growth and flow of literature in a particular publication field [12]. This bibliometric study uses empirical data to track existing publications [13]. This study can analyze the distribution of manuscripts sorted by country, source, year and more [14].

This research was carried out with an explanation of the importance of digital learning as well as the existing shortcomings. The aim is to analyze top 100 highest citations of digital learning research topics, and the important role of interactive learning in physics from 1992 to 2021. For analysis are used bibliometrics and also literature review. The objective research included:

1. Analysis of the trend of digital learning publications from the last thirty years.
2. Identifying the most widely used keywords, the country and author that contribute the most to the publication of digital learning in the last thirty years.
3. Identifying document types and source titles for digital learning from the last thirty years.
4. Identifying the year wise distribution of the top 100 cited digital learning publications from the last thirty years.
5. Identifying the contribution of digital learning in physics learning over the last thirty years.
6. Identifying the advantages and disadvantages of digital learning.
7. Analysis of the important role of interactive learning in physics.

2. Methods

This study uses bibliometric analysis and literature review. The data used in this study were taken from Scopus. Scopus is well-known for its largest database of publications in various fields including academic fields such as natural sciences, computing and others [15], [16]. Data from Scopus can be adjusted according to the needs of the year, title, country, keywords, and so on [17]. In addition, this study uses a literature review from previous studies as a reinforcement of research data.

Research data was taken on April 1, 2022. The data in Scopus is selected based on the keywords you want to search for. In this study, the keyword selection stage was carried out twice, the first regarding digital learning. Furthermore, the second keywords are connected with physics learning to find the contribution of digital learning, more details can be seen in Figure 1. The data was obtained in the form of .csv which was then analyzed using Microsoft excel and .ris which was analyzed using VOSViewer [18].

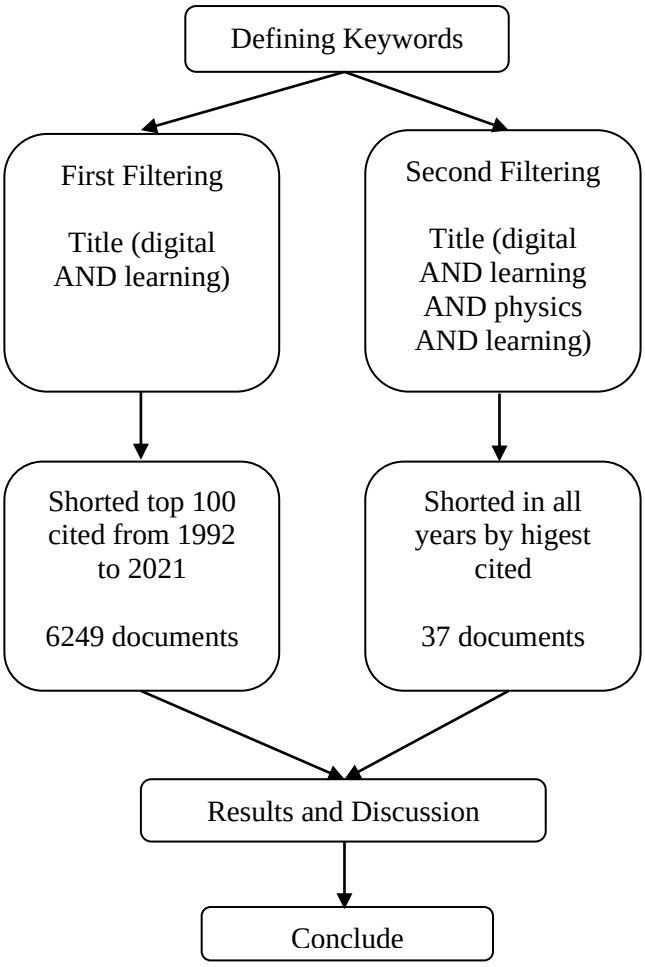

Figure 1. Flowchart for the keyword filtering

3. Results and discussion

3.1 Publication trend in the last 30 years

From Figure 2., we can see the trend of publications related to digital learning. The trend of publication is an important aspect to pay attention to and follow up [19]. Considering that publications must be in accordance with current conditions, which mean the development of a topic is determined from the trend of publications each year [20].

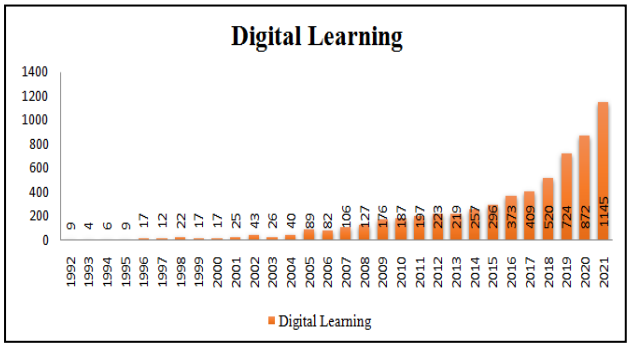

Figure 2. Digital learning publication trends

The highest digital learning publication was in 2021 with 1145 documents and the lowest in 1993 with 4 documents. Digital learning publications began to increase steadily, from 2014 to 2021. The highest increase occurred in 2021 with as many as 273 documents from 2020. The researchers tend to be interested in raising the topic of digital learning [21]. This is in line with the fact that the majority of education in the world has used digital learning due to the emergence of the Covid-19 pandemic [22]. So that research related to digital learning has high potential for future research.

3.2 Visualization of the most used keywords, top countries and top authors who contributed the most

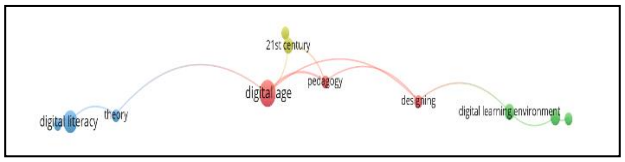

Figure 3. The keywords visualization of digital learning

Figure 3. shows the keyword visualization using VOSViewer. Keywords can describe the subject matter in a publication [23]. For digital learning topics, the most commonly used keyword is "digital age" which has 8 occurrences and "digital literacy" has 6 occurrences.

Table 1. Comparison of the top 10 countries with the most publications in the last thirty years

Top 10 countries	Publications
United States	1,359
United Kingdom	460
China	422
Germany	347
Australia	319
Taiwan	306
Spain	281
Indonesia	221
Canada	208
India	187

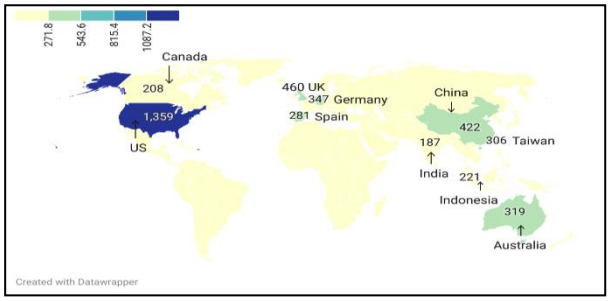

Figure 4. Top 10 Countries with publications about digital learning

From Table 1. and Figure 4., it can be concluded that the United States produced the highest number of papers over the last thirty years on the topic of digital learning. There are five countries that consistently occupy the top 10 on all publication topics related to digital learning including the United States, China, United Kingdom, Australia and Spain. To identify the author who has the most publications on each topic of digital learning, we were using VOS viewer and Microsoft Excel analysis. The results of the Microsoft Excel analysis are shown in Table 2.

Table 2. The top 10 author with the highest citations in the last thirty years

Author	Total Citations	Country
M. Papastergiou	1,880	Greece
K. Kiili	1,978	Finland
C.M. Greenhow	2,509	United States
A.R. Janowczyk	1,269	United States
D.B. Clark	3,069	Canada
A. Madabhushi	14,845*	United States
B. Gros	660	Spain
S. Erhel	429	France
A. Sadik	367	Egypt
B.Q. Huynh	590	United States

Table 2. shows the top 10 authors from the highest citations for the topic of digital learning, M. Papastergiou from Greece. Meanwhile, the highest total citation was owned by A. Madabhushi from the United States. To find out which writers on digital learning topics produce the most digital learning papers and who are most connected to other authors, we can use a software called VOSViewer. With VOSViewer we can identify the classification of top authors [24]. The grouping and connection of each author is indicated by the presence of clusters [25]. The first results of the digital learning topic are divided into 3 clusters, namely red (n=5), green (4), blue (n=2). H. Beetham is the main author because he has 3 documents with 2 total links strength which is more than any other author.

3.3 The document types and source titles of top 100 highest cited publications in the last 30 years

Table 3. The document types of top 100 highest cited digital learning publication in the last 30 years

Document Type	Freq-uency	Cited	Mean	Med-ian	SD
Article	81*	14206*	175.3	125	160.8*
Conference paper	7	808	115.4	95	47.2
Review	4	810	202.5*	209.5*	96.6
Note	0	0	0	0	-
Book	7	1011	144.4	129	63.1
Editorial	1	376	376	376	-

Table 3. shows digital learning topics, most of the publications are in the form of articles (n=81). Digital learning has been totally cited 14,206. The standard deviation is quite high, namely digital learning (n=160.8).

Table 4. The source titles of top 100 highest cited publication in the last 30 years

Source Title	TD	TC
Computers and Education	13	2983
Educational Technology and Society	4	415
Journal of Computer Assisted Learning	3	565
Journal of Research on Technology in Education	3	530
Language and Learning in the Digital Age	3	468
Geoderma	3	386
ReCALL	3	325
Internet and Higher Education	2	1008
Rethinking Pedagogy for a Digital Age: Designing and Delivering E-Learning	2	343
Learning, Media and Technology	2	264
TD = Total Documents TC = Total Citations		

Table 4. shows that the source titles of digital learning are varied and we can see that the source title which produces the most digital learning topics, namely Computers and Education (n=13 documents). The highest total citation is 2,983 namely source title is Computers and Education.

3.4 The year wise distribution of top 100 highest cited publications in the last 30 years

Table 5. contains information on the distribution of the top 100 cited publications on the topics of digital learning. The range of data used is from 1992 to 2021.

Table 5. The year wise distribution of top 100 highest cited publications in the last 30 years

Year	Citable Year	Digital Learning			
		TC	TD	ACPP	ACPPY
1992	30	0	0	0	0
1993	29	0	0	0	0
1994	28	0	0	0	0
1995	27	215	2	107.5	3.9
1996	26	0	0	0	0
1997	25	0	0	0	0
1998	24	0	0	0	0
1999	23	0	0	0	0
2000	22	0	0	0	0
2001	21	420	2	210	10
2002	20	0	0	0	0
2003	19	0	0	0	0
2004	18	454	2	227	12.6
2005	17	1237	4	309.2*	18.2
2006	16	270	2	135	8.4
2007	15	891	5	178.2	11.8
2008	14	869	5	173.8	12.4
2009	13	2282	7	326	25.1
2010	12	421	3	140.3	11.6
2011	11	932	7	133.1	12.1
2012	10	1327	10	132.7	13.3
2013	9	1199	7	171.3	19
2014	8	894	8	111.7	13.9
2015	7	443	4	110.7	15.8
2016	6	2699*	11*	245.4	40.9
2017	5	567	4	141.7	28.4
2018	4	881	6	146.8	36.7
2019	3	884	9	98.2	32.7
2020	2	326	2	163	81.5*
2021	1	0	0	0	0
*The Highest Number					

This information can be used to see in what year the top 100 cited publications were produced on the topic. From this study it was found that the highest year is 2016 (n=11 documents). In addition, from this study it was found that the highest year is 2016 (n=2,699 citations). The highest average citation per paper per year in 2020 is 81,5.

3.5 Literature review of digital learning to physics learning

Table 6. contains the results of the literature review by taking into account the quartiles, citations, and findings to provide recommendations regarding the selected paper.

Table 6. Top 5 highest cited paper showing contribution of digital learning to physics learning

Author	SJR	Citation	Findings
Anderson, J. L., & Barnett, M. [26]	1,03 (Q1)	46	Digital learning with game simulations has a positive impact on the learning outcomes of junior high school students in physics learning.
Sengupta, P., Krinks, K. D., & Clark, D. B. [27]	4,06 (Q1)	22	The results of the study show that the combination of using digital learning fosters student physics learning motivation.
Melo, M. [28]	0,54 (Q2)	4	The use of digital learning 4C/ID model in physics content to students has a positive impact on learning outcomes.
Euler, E., Prytz, C., & Gregorcic, B. [29]	0,34 (Q3)	1	Digital learning using the Algodoo application gives students the opportunity to explore physics learning materials for free and able to attract students' attention in learning.
Sukarno & Widdah, M.E. [30]	0,49 (Q2)	1	Students' metacognitive and digital literacy skills increase in physics learning.

The ranking system of reputable journals based on the subject or category of the related journal field is also called quartiles [31]. From these results, it can be seen that the topic of digital learning has the highest citation 46, thus, research related to digital learning in physics will have a lot of potentials, and its novelty will be quite high. Digital learning tends to take advantage of interactive learning applications to increase student motivation and learning outcomes [32].

3.6 Advantage and disadvantage of digital learning to physics learning

Table 7. Discussion about digital learning

Discussion	Digital Learning
Meaning	Learning media that can be done digitally without having to wait for internet access to start.
Characteristics	• Some digital learning can be accessed without internet • Not tied to face-to-face or non-face-to-face learning • More towards the learning media
Advantage	Can be used in various places, can trigger students to think creatively and innovatively
Disadvantage	Can lead to dependence on digital tools so that it can cause laziness in students

From table 7., broadly speaking, it can be concluded that digital learning has advantages in flexibility and types of media that utilize sophisticated digital tools. While the disadvantages have an impact on students' lifestyles which can become dependent on digital learning media.

3.7 Analysis of the important role of interactive learning in physics based on digital learning research

Learning physics still tends to be difficult for most students to understand. Physics learning needs to be set more interactively for students. The use of interactive learning media can be integrated using a combination of video, graphics, text, and sound. Digital learning by applying interactive virtual reality can deepen students' understanding of physics material. In addition, through good quality worksheets in digital learning can be improved the students' critical thinking skills in learning physics. Practical activities can play an important role in engaging students with the world of science, especially when using digital tools. So, it can be concluded that interactive learning can improve student learning outcomes [33].

The majority of students in the 21st century is proficient in advanced technology and are adaptable. For example, the use of interactive modules is also very important to apply because, according to research [34], digital learning of physics with interactive modules shows compatibility and a positive impact. Since the last three years, the world has been affected by the pandemic, so academic units must also think about effective learning methods that can still improve student achievement. Therefore, interactive learning in physics is starting to be more widely applied. One of them is by using interactive multimedia, which is able to improve students' understanding of concepts [35]. Interactive learning plays an important role in deepening the concept of physics and making the learning atmosphere more interesting even through digital learning.

4. Conclusion

Research results analysis using bibliometric studies and literature reviews related to digital learning research get several conclusions. The conclusion is that the trend of digital learning topics is increased steadily, from 2014 to 2021. The most commonly used keywords are digital age, and digital literacy. The United States (US) has made the highest contribution over the last thirty years on digital learning. The author with the highest citation on digital learning is M. Papastergiou from Greece. The type of document that is often published by the author is in the form of articles. The highest source titles digital learning is the paper *Computers and Education*. The highest average citation per paper per year is in 2020 where digital learning (n=81,5). The digital learning topics contribute to learning physics. From the explanation above, the future research related to digital learning in physics will have a lot of potentials, and its novelty will be quite high. The important role of interactive learning in physics is to improve student learning outcomes, train critical thinking skills, deepen understanding of concepts and make learning more interesting. The advantages of digital learning is in flexibility such as the learning process can be carried out even though it is not face-to-face, reducing learning hours and types of media that utilize sophisticated digital tools. While the disadvantages have an impact on students' lifestyles which can become dependent on digital learning media and because it’s using the internet network, which requires costs and a strong signal because not all areas have a strong network connection.

The implication of this research is to show the trend of publication of digital learning topics so that future researchers can show more benefits related to these topics. With this article, researchers can find out the strengths and weaknesses of digital learning topic and can find updates for future research. The limitation of the study is that some research results at Scopus are limited to full access. More intensively, further research can be carried out by comparing other learning systems applied in physics learning.

5. Acknowledgement

The author's gratitude goes to the *Direktorat Jenderal Pendidikan Tinggi, Riset, dan Teknologi; Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, Indonesia* who has supported funding in *Penelitian Dasar Unggulan Perguruan Tinggi* - DRTPM 2022 [Contract Number: 29551/UN38.9/LK.04.00/2022].

References

[1] Dias Canedo E., Aymoré Martins V., Coelho Ribeiro V., dos Reis V.E., Carvalho Chaves L.A., Machado Gravina R., Alberto Moreira Dias F., Lopes de Mendonça F.L., Orozco A.L.S., Balaniuk R., de Sousa R.T Jr. (2021). Development and Evaluation of an Intelligence and Learning System in Jurisprudence Text Mining in the Field of Competition Defense. *Applied Sciences*, 11(23), 11365. https://doi.org/10.3390/app112311365

[2] Hsu, F. H., Lin, I. H., Yeh, H. C., & Chen, N. S. (2022). Effect of Socratic Reflection Prompts via video-based learning system on elementary school students' critical thinking skills. *Computers & Education*, *183*, 104497. https://doi.org/10.1016/j.compedu.2022.104497

[3] Hassan, T. (2022). A global update on covid-19 pandemic: Vaccines and new variants. *Pakistan Journal of Medicine & Dentistry*, 11(1), 89-93. https://doi.org/10.36283/PJMD11-1/015

[4] Donham, C., Barron, H. A., Alkhouri,J. S., Kumarath, M. C., Alejandro, W., Menke, E., & Kranzfelder, P. (2022). I will teach you here or there, I will try to teach you anywhere: perceived supports and barriers for emergency remote teaching during the COVID-19 pandemic. *International Journal of STEM Education*, 9(19), 1-25. https://doi.org/10.1186/s40594-022-00341-3

[5] Temelli, D. (2022). Reflexes of international organizations regarding education in the covid-19 pandemic process and comparing implementations in turkey. *Milli Egitim*, 51(233), 887-909. https://doi.org/10.37669/milliegitim.788444

[7] Olmes, G. L., Zimmermann, J. S. M., Stotz, L., Takacs, F. Z., Hamza, A., Radosa, M. P., Findeklee, S., Solomayer, E. F.,&Radosa, J. C. (2021). Students' attitudes toward digital learning during the covid-19 pandemic: a survey conducted following an online course in gynecology and obstetrics. *Archives of Gynecology and Obstetrics*, 304(4), 957-963. https://doi.org/10.1007/s00404-021-06131-6

[8] Guppy, N., Verpoorten, D., Boud, D., Lin, L., Tai. J., & Bartolic, S. (2022). The post-COVID-19 future of digital learning in higher education: Views from educators, students, and other professionals in six countries. *British Journal of Educational Technology*, 1(1), 1-22. https://doi.org/10.1111/bjet.13212

[9] Adde, D., Amponsah, S., & Gborti, B. J. (2022). Covid-19 pandemic and the shift to digital learning: experiences of students in a community college in ghana. *Community College Journal of Research and Practice*, 46(1), 101-112. https://doi.org/10.1080/10668926.2021.1972364

[10] Poluakan, C., & Katuuk, D. (2021). PIMCA: a new alternativesto physics learning model. *Journal of Physics: Conference Series*, 2165, 1-6.https://doi.org/10.1088/1742-6596/2165/1/012013

[11] Ivanec, T. P. (2022). The lack of academic social interactions and students' learning difficulties during covid-19 faculty lockdowns in Croatia: the mediating role of the perceived sense of life disruption caused by the pandemic and the adjustment to online studying. *Journal Social Science*, 11(42), 1-11. https://doi.org/10.3390/socsci11020042

[12] Vieyra, R., & Himmelsbach, J. (2022). Teachers' disciplinary boundedness in the implementation of integrated computational modeling in physics. *Journal of Science Education and Technology*, 31(2), 153-165. https://doi.org/10.1007/s10956-021-09938-9

[13] Dewantara, D., Sofianto, E. W. N., Misbah, & Munawaroh, D. (2021). Physics e-module: A review and bibliometric analysis. *Journal of Physics: Conference Series*, 2104, 1-7. https://doi.org/10.1088/1742-6596/2104/1/012008

[14] 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), 136-154. https://doi.org/10.3991/ijim.v15i08.20415

[15] Wang, J., Shen, L.,& Zhou, W. (2021). A bibliometric analysis of quantum computing literature: mapping and evidences from Scopus. *Technology Analysis and Strategic Management*, 33(11), 1347-1363. https://doi.org/10.1080/09537325.2021.1963429

[16] Kamaruzzaman, W. M., Nasir, N., Hamidi, N. A., Yusof, N., Shaifudin, M. S., Suhaimi, A. M. A. A. M., Badruddin, M. A., Adnan, A., Nik, W. M. N. W., & Ghazali, M. S. M. (2022). 25 years of progress on plants as corrosion inhibitors through a bibliometric analysis using the Scopus database (1995–2020). *Arabian Journal of Chemistry*, 15(4), 4-19. https://doi.org/10.1016/j.arabjc.2021.103655

[17] Kulkanjanapiban, P., & Silwattananusarn T. (2022). Comparative analysis of Dimensions and Scopus bibliographic data sources: An approach to university research productivity. *International Journal of Electrical and Computer Engineering*, 12(1) 706-720. https://doi.org/10.11591/ijece.v12i1.pp706-720

[18] Putri, C. R., Soleh, S. M., Saregar, A., Anugrah, A., &Susilowati, N. E. (2021). Bibliometric analysis: Augmented reality-based physics laboratory with VOSviewer software. *Journal of Physics: Conference Series*, 1796, 1-12. https://doi.org/10.1088/1742-6596/1796/1/012056

[19] Nishioka, C., & Farber, M. (2020). Trends of publications' citations and altmetrics based on open access types. Proceedings of the ACM/IEEE Joint Conference on Digital Libraries, 503-504. https://doi.org/10.1145/3383583.3398584

[20] Soehartono, A. M., Yu, L. G., & Khor, K. A. (2022). Essential signals in publication trends and collaboration patterns in global Research Integrity and Research Ethics (RIRE). *Scientometrics*, 1-11. https://doi.org/10.1007/s11192-022-04400-y

[21] Sousa, M. J., & Rocha, A. (2018). Special section on "emerging trends and challenges in digital learning". *Universal Access in the Information Society*, 17(4), 675-677. https://doi.org/10.1007/s10209-017-0572-6

[22] Zhao, L., Cao, C., Li, Y., & Li, Y. (2022). Determinants of the digital outcome divide in e-learning between rural and urban students: empirical evidence from the covid-19 pandemic based on capital theory. *Computers in Human Behavior*,130(1), 1-15. https://doi.org/10.1016/j.chb.2021.107177

[23] 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 and biomedical engineering*, 17(10), 144-159. https://doi.org/10.3991/ijoe.v17i10.25243

[24] Effendi, D. N., Irwandani, Anggraini, W., Jatmiko, A., Rahmayanti, H., Ichsan, I. Z., & Rahman, M. M. (2021). Bibliometric analysis of scientific literacy using VOS viewer: Analysis of science education. *Journal of Physics: Conference Series*, 1796, 1-10. https://doi.org/10.1088/1742-6596/1796/1/012096

[25] Pristianti, M. C. (2022). Top 100 cited research of confirmatory factor analysis (CFA) in education from 2012 to 2021. *International Journal of Current Educational Research*, 1(1), 68-83. https://doi.org/10.53621/ijocer.v1i1.140

[26] Anderson, J. L., & Barnett, M. (2013). Learning physics with digital game simulations in middle school science. *Journal of Science Education and Technology*, 22(6), 914-926. https://doi.org/10.1007/s10956-013-9438-8

[27] Sengupta, P., Krinks, K. D., & Clark, D. B. (2015). Learning to deflect: conceptual change in physics during digital gameplay. *Journal of the Learning Sciences*, 24(4), 638-674. http://dx.doi.org/10.1080/10508406.2015.1082912

[28] Melo M. (2018). The 4C/ID-model in physics education: Instructional design of a digital learning environment to teach electrical circuits. *International Journal of Instruction*, 11(1), 103-122. https://doi.org/10.12973/iji.2018.1118a

[29] Euler, E., Prytz, C., & Gregorcic, B. (2020). Never far from shore: Productive patterns in physics students' use of the digital learning environment Algodoo. *Physics Education*, 55(4), 1-8. https://doi.org/10.1088/1361-6552/ab83e7

[30] Sukarno & Widdah, M.E. (2020). The effect of students' metacognition and digital literacy in virtual lectures during the covid-19 pandemic on achievement in the "methods and strategies on physics learning" course. *Jurnal Pendidikan IPA Indonesia*, 9(4), 477-488. https://doi.org/10.15294/jpii.v9i4.25332

[31] Arianto, M. A. & Basthomi, Y. (2021). The authors' research gap strategies in elt research article introductions: does Scopus journal quartile matter?. *Journal of Language and Linguistic Studies*, 17(4), 1743-1759. https://doi.org/10.52462/jlls.127

[32] Engerman, J. A., & Otto, R. F. (2021). The shift to digital: designing for learning from a culturally relevant interactive media perspective. *Educational Technology Research and Development*, 69(1), 301-305. https://doi.org/10.1007/s11423-020-09889-9

[33] Balaton, M., Cavadas, J., Carvalho, P. S., & Lima, J. J. G. (2021). Programming ozobots for teaching astronomy. *Physics Education*, 56(4), 1-8. https://doi.org/10.1088/1361-6552/abfb44

[34] Wongsuwan, W., Huntula, J.,&Liu, C. C. (2022).The interactive computer simulation and learning activity for facilitating students' conceptual understanding on the buoyant force through the CoSci learning platform. *Journal of Physics: Conference Series*, 2145, 1-6. https://doi.org/10.1088/1742-6596/2145/1/012075

[35] Susilowati, N. E., Samsudin, A., & Muslim. (2021). What do physics teachers need? A need analysis of interactive multimedia to train creative thinking in static fluid. *Journal of Physics: Conference Series*, 2098, 1-6. https://doi.org/10.1088/1742-6596/2098/1/012029

Digital Learning Research in The Last 30 Years: Important Role of Interactive Learning in Physics

Binar Kurnia Prahani[1], Mila Candra Pristianti[1], Budi Jatmiko[1], Tan Amelia[2], Firmanul Catur Wibowo[3]

[1]*Universitas Negeri Surabaya, Surabaya, Indonesia*
[2]*Universitas Dinamika,Surabaya, Indonesia*
[3] *Universitas Negeri Jakarta,Jakarta, Indonesia*
binarprahani@unesa.ac.id

***Abstract* – The aim is to analyze top 100 highest citations of digital learning research topic and the important role of interactive learning in physics learning in 1992-2021. This study uses bibliometric analysis and literature review. The trend of digital learning topics is increase steadily, from 2014 to 2021. Digital learning shows an excellent contribution to physics learning. The important role of interactive learning in physics are to improve student learning outcomes, deepen understanding and make learning more interesting. More intensively, further research can be carried out by comparing other learning systems applied in physics learning.**

***Keywords* – Bibliometric, Digital Learning, Education, Physics Learning**

1. Introduction

Various kinds of learning system have been applied according to surrounding conditions, the examples are digital learning. The development of learning systems must pay attention to the ease of adaptation and transformation [1],[2]. Learning development can be done by combining organizational learning theory and general systems theory.

There are many impacts of the covid-19 pandemic, one of which is in the world of education. One of the updates on October 10, 2021, the entire country has reported 219 million cases with 4.55 million deaths [3]. With the danger that threatens, many countries are trying to make learning sustainable [4]. Efforts are made to organize healthy learning during the covid-19 pandemic crisis [5]. The covid-19 outbreak caused the closure of schools and colleges, so that educational institutions designed more flexible. Research conducted by Leonhard [6], Neil [7], and David [8] concluded that during the covid-19 pandemic, student responses showed good acceptance of digital learning. Students accept and adapt easily to digital technology during the covid-19 pandemic.

Physics learning is closely related to natural phenomena and experimental activities. The flexible of physics learning can be done use digital technology or without it [9]. By learning physics through digital learning students are challenged to be more independent, must be easy to adapt and willing to learn. However, there are shortcomings in the implementation of digital learning, namely some places have limited access to digital media, and potential dependence on digital technology [10]. Mentoring and supervision by physics teachers will determine the success of digital learning [11].

From existing studies, there is still no discussion that show the contribution digital learning in physics learning and important role of interactive learning in physics. Some studies tend to discuss digital learning, but to show the right data regarding the analysis, bibliometric studies and literature reviews

DOI: 10.18421/TEMxx-xx
https://doi.org/10.18421/TEMxx-xx

Corresponding author: Binar Kurnia Prahani, Universitas Negeri Surabaya, Indonesia

Email: binarprahani@unesa.ac.id

Received: -----.
Accepted: -----.
Published: -----.

are needed. Bibliometric analysis is a method to provide knowledge regarding the growth and flow of literature in a particular publication field [12]. This bibliometric study uses empirical data to track existing publications [13]. This study can analyze the distribution of manuscripts sorted by country, source, year and more [14].

With an explanation of the importance digital learning as well as the existing shortcomings, this research was carried out. The aim is to analyze top 100 highest citations of digital learning research topic, and the important role of interactive learning in physics from 1992 to 2021. For analysis using bibliometrics and also literature review. The objective research include:

1. Analyze the trend of digital learning publications from the last thirty years.
2. Identify the most widely used keywords, the country and author that contribute the most to the publication of digital learning in last thirty years.
3. Identify document types and source titles for digital learning from the last thirty years.
4. Identify the year wise distribution of the top 100 cited digital learning publications from the last thirty years.
5. Identify the contribution digital learning in physics learning over the last thirty years.
6. Identify the advantages and disadvantages of digital learning.
7. Analyze the important role of interactive learning in physics.

2. Methods

This study uses bibliometric analysis and literature review. The data used in this study were taken from Scopus. Scopus is well-known for its largest database of publications in various fields including academics [15],[16]. Data from Scopus can be adjusted according to the needs of the year, title, country, keywords, and so on [17]. In addition, this study uses a literature review from previous studies as a reinforcement of research data.

Research data taken on April 1, 2022. The data in Scopus is selected based on the keywords you want to search for. In this study, the keyword selection stage was carried out twice, the first regarding digital learning. Furthermore, the second keyword are connected with physics learning to find the contribution of digital learning, formore details can be seen in Figure 1. The data obtained in the form of .csv which was then analyzed using Microsoft excel and .ris which was analyzed using VOSViewer [18].

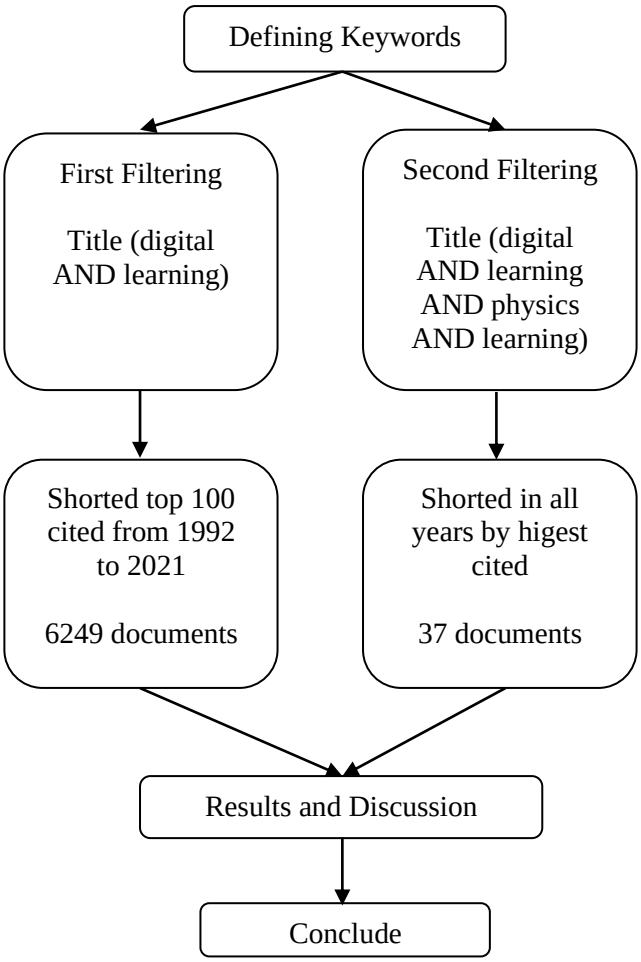

Figure 1. Flowchart for the keyword filtering

3. Results and Discussion

3.1 Publication Trend in Last 30 Years

From Figure 2, we can see the trend of publications related to digital learning. The trend of publication is an important aspect to pay attention to and follow up [19]. Considering that publications must be in accordance with current conditions, which mean the development of a topic is determined from the trend of publications each year [20].

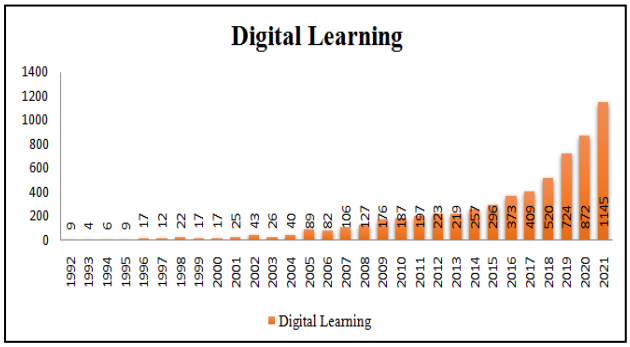

Figure 2. Digital learning publication trends

The highest digital learning publication in 2021 with 1145 documents and the lowest in 1993 with 4 documents. Digital learning publications began to

increase steadily, from 2014 to 2021. The highest increase occurred in 2021 as many as 273 documents from 2020. The researchers tend to be interested in raising the topic of digital learning [21]. This is in line with the fact that the majority of education in the world has used digital learning due to the emergence of the Covid-19 pandemic [22]. So that research related to digital learning has high potential for future research.

3.2 Visualization of The Most Used Keywords, Top Countries and Top Authors Who Contributed the Most

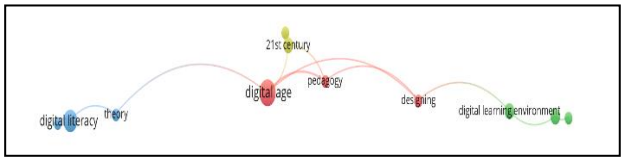

Figure 3. The keywords visualization of digital learning

Figure 3shows the keyword visualization using VOSViewer. Keywords can describe the subject matter in a publication [23]. For digital learning topics, the most commonly used keyword is "digital age" which has 8 occurrences and "digital literacy" has 6occurrences.

Table 1. Comparison of the top 10 countries with the most publications in the last thirty years

Top 10 countries	Publications
United States	1,359
United Kingdom	460
China	422
Germany	347
Australia	319
Taiwan	306
Spain	281
Indonesia	221
Canada	208
India	187

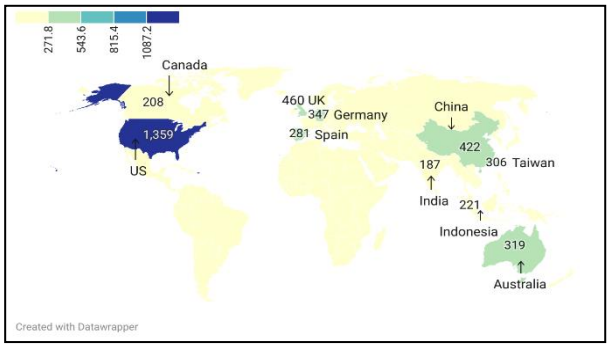

Figure 4. Top 10 Countries with publications about digital learning

From Table 1 and Figure 4, it can be concluded that the United States has the highest contribution over the last thirty years both on the topic of digital learning. There are five countries that consistently occupy the top 10 on all publication topics related to digital learning including the United States, China, United Kingdom, Australia and Spain. To identify the author who has the most publications on each topic of digital learning, using VOS viewer and Microsoft Excel analysis. The results of the Microsoft Excel analysis are shown in Table 2.

Table 2. The top 10 author with the highest citations in the last thirty years

Author	Total Citations	Country
M. Papastergiou	1,880	Greece
K. Kiili	1,978	Finland
C.M. Greenhow	2,509	United States
A.R. Janowczyk	1,269	United States
D.B. Clark	3,069	Canada
A. Madabhushi	14,845*	United States
B. Gros	660	Spain
S. Erhel	429	France
A. Sadik	367	Egypt
B.Q. Huynh	590	United States

Table 2 shows the top 10 authors from the highest citations for the topic of digital learning, M. Papastergiou from Greece. Meanwhile, the highest total citation was owned by A Madabhushi came from the United States.To find out who the author on the topic of digital learning is the most contributing and connected is using VOSViewer. With VOSViewer we can identify the classification of top authors [24]. The grouping and connection of each author is indicated by the presence of clusters [25]. The first result of the digital learning topic is divided into 3 clusters, namely red (n=5), green (4), blue (n=2). H. Beetham is the main author because he has 3 documents with 2 total link strength which is more than any other author.

3.3The Document Types and Source Titles of Top 100 Highest Cited Publication in Last 30 Years

Table 3. The document types of top 100 highest cited digital learning publication in last 30 years

Document Type	Freq-uency	Cited	Mean	Med-ian	SD
Article	81*	14206*	175.3	125	160.8*
Conference paper	7	808	115.4	95	47.2
Review	4	810	202.5*	209.5*	96.6
Note	0	0	0	0	-
Book	7	1011	144.4	129	63.1
Editorial	1	376	376	376	-

Table 3 shows on digital learning topic, the most publications are in the form of articles (n=81). Digital learning has the total cited is 14,206. The standard deviation is quite high, namely digital learning (n=160.8).

Table 4. The source titles of top 100 highest cited publication in last 30 years

Source Title	TD	TC
Computers and Education	13	2983
Educational Technology and Society	4	415
Journal of Computer Assisted Learning	3	565
Journal of Research on Technology in Education	3	530
Language and Learning in the Digital Age	3	468
Geoderma	3	386
ReCALL	3	325
Internet and Higher Education	2	1008
Rethinking Pedagogy for a Digital Age: Designing and Delivering E-Learning	2	343
Learning, Media and Technology	2	264
TD = Total Documents TC = Total Citations		

Table 4 shows the source titles of digital learning are varied. For the highest source title digital learning namely Computers and Education (n=13 documents). The highest total citation is 2,983 namely source title is Computers and Education.

3.4 The Year Wise Distribution of Top 100 Highest Cited Publication in Last 30 Years

Table 5 contains information on the distribution of the top 100 cited publications on the topics of digital learning. The range of data used is from 1992 to 2021.

Table 5.The year wise distribution of top 100 highest cited publication in last 30 years

Year	Citable Year	Digital Learning			
		TC	TD	ACPP	ACPPY
1992	30	0	0	0	0
1993	29	0	0	0	0
1994	28	0	0	0	0
1995	27	215	2	107.5	3.9
1996	26	0	0	0	0
1997	25	0	0	0	0
1998	24	0	0	0	0
1999	23	0	0	0	0
2000	22	0	0	0	0
2001	21	420	2	210	10
2002	20	0	0	0	0
2003	19	0	0	0	0
2004	18	454	2	227	12.6
2005	17	1237	4	309.2*	18.2
2006	16	270	2	135	8.4
2007	15	891	5	178.2	11.8
2008	14	869	5	173.8	12.4
2009	13	2282	7	326	25.1
2010	12	421	3	140.3	11.6
2011	11	932	7	133.1	12.1
2012	10	1327	10	132.7	13.3
2013	9	1199	7	171.3	19
2014	8	894	8	111.7	13.9
2015	7	443	4	110.7	15.8
2016	6	2699*	11*	245.4	40.9
2017	5	567	4	141.7	28.4
2018	4	881	6	146.8	36.7
2019	3	884	9	98.2	32.7
2020	2	326	2	163	81.5*
2021	1	0	0	0	0
*The Highest Number					

This information can be used to see in what year the top 100 cited publications were produced on the topic. From this study it was found that the highest year is 2016 (n=11 documents). In addition, from this study it was found that the highest year is 2016 (n=2,699 citations). The highest average citation per paper per year in 2020 is 81,5.

3.5 Literature Review of Digital Learning to Physics Learning

Table 6contains the results of the literature review by taking into account the quartiles, citations, and findings to provide recommendations regarding the selected paper.

Table 6. Top 5 highest cited paper showed contribution of digital learning to physics learning

Author	SJR	Citation	Findings
Anderson, J. L., & Barnett, M. [26]	1,03 (Q1)	46	Digital learning with game simulations has a positive impact on the learning outcomes of junior high school students in physics learning.
Sengupta, P., Krinks, K. D., & Clark, D. B. [27]	4,06 (Q1)	22	The results of the study show that the combination of using digital learning fosters student physics learning motivation
Melo, M. [28]	0,54 (Q2)	4	The use of digital learning 4C/ID model in physics content to students has a positive impact on learning outcomes.
Euler, E., Prytz, C., & Gregorcic, B. [29]	0,34 (Q3)	1	Digital learning using the Algodoo application gives students the opportunity to explore physics learning materials for free and able to attract students' attention in learning
Sukarno & Widdah, M.E. [30]	0,49 (Q2)	1	Students' metacognitive and digital literacy skills increase in physics learning.

The ranking system of reputable journals based on the subject or category of the related journal field is

also called quartiles [31]. From these results, it can be seen that the topic of digital learning has the highest citation is 46, thus, research related to digital learning in physics will have a lot of potentials, and its novelty will be quite high. Digital learning tends to take advantage of interactive learning applications to increase student motivation and learning outcomes [32].

3.6 Advantage and Disadvantage of Digital Learning to Physics Learning

Table 7. Discussion about digital learning

Discussion	Digital Learning
Meaning	Learning media that can be done digitally without having to wait for internet access to start.
Characteristics	• Some digital learning can be accessed without internet • Not tied to face-to-face or non-face-to-face learning • More towards the learning media
Advantage	Can be used in various places, can trigger students to think creatively and innovatively
Disadvantage	Can lead to dependence on digital tools so that it can cause laziness in students

Table 7 broadly speaking, it can be concluded that digital learning has advantages in flexibility and types of media that utilize sophisticated digital tools. While the disadvantages have an impact on students' lifestyles which can become dependent on digital learning media. The digital learning is a learning process that requires internet access, while digital learning does not always require internet access.

3.7 Analyze the Important Role of Interactive Learning in Physics Based on Digital Learning Research

Learning physics still tends to be difficult for most students to understand. Physics learning needs to be set more interactively for students. The use of interactive learning media can be integrated using a combination of video, graphics, text, and sound. Digital learning by applying interactive virtual reality can deepen students' understanding of physics material. In addition, through good quality worksheets in digital learning can improve students' critical thinking skills in learning physics. Practical activities can play an important role in engaging students with the world of science, especially when using digital tools. So, it can be concluded that interactive learning can improve student learning outcomes [33].

The majority of students in the 21st century is proficient in advanced technology and are adaptable. For example, the use of interactive modules is also very important to apply because, according to research [34], digital learning of physics with interactive modules shows compatibility and a positive impact. Since the last three years, the world has been affected by the pandemic, so academic units must also think about effective learning methods that can still improve student achievement. Therefore, interactive learning in physics is starting to be more widely applied. One of them is by using interactive multimedia, which is able to improve students' understanding of concepts [35]. Interactive learning plays an important role in deepening the concept of physics and making the learning atmosphere more interesting even though digital learning.

4. Conclusion

Research results analysis using bibliometric studies and literature reviews related to digital learning research get several conclusions. The conclusion is that the trend of digital learning topics is increase steadily, from 2014 to 2021. The most commonly used keywords are digital age, and digital literacy. United States (US) has made the highest contribution over the last thirty years on digital learning. The author with the highest citation on digital learning is M. Papastergiou from Greece. The type of document that is often published in the article. The highest source titles digital learning, namely Computers and Education. The highest average citation per paper per year is in 2020 where digital learning (n=81,5). The digital learning topic contribute to learning physics. From explanation above, the future research related to digital learning in physics will have a lot of potentials, and its novelty will be quite high. The important role of interactive learning in physics is to improve student learning outcomes, train critical thinking skills, deepen understanding of concepts and make learning more interesting. The advantages in flexibility and types of media that utilize sophisticated digital tools. While the disadvantages have an impact on students' lifestyles which can become dependent on digital learning media and because it’s using the internet network, which requires costs and a strong signal because not all areas have a strong network connection.

The implication of this research is to show the trend of publication of digital learning topics so that future researchers can show more benefits related to these topics. With this article, researchers can find out the strengths and weaknesses of digital learning topic and can find updates for future research. The limitation of the study is that some research results at Scopus are limited to full access. More intensively, further research can be carried out by comparing other learning systems applied in physics learning.

5. Acknowledgement

The author's gratitude goes to the *Direktorat Jenderal Pendidikan Tinggi, Riset, dan Teknologi; Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, Indonesia* who has supported funding in *Penelitian Dasar Unggulan Perguruan Tinggi* - DRTPM 2022 [Contract Number: 29551/UN38.9/LK.04.00/2022].

References

[1] Dias Canedo E., Aymoré Martins V., Coelho Ribeiro V., dos Reis V.E., Carvalho Chaves L.A., Machado Gravina R., Alberto Moreira Dias F., Lopes de Mendonça F.L., Orozco A.L.S., Balaniuk R., de Sousa R.T Jr. (2021). Development and Evaluation of an Intelligence and Learning System in Jurisprudence Text Mining in the Field of Competition Defense. *Applied Sciences*, 11(23), 11365.https://doi.org/10.3390/app112311365

[2] Hsu, F. H., Lin, I. H., Yeh, H. C., & Chen, N. S. (2022). Effect of Socratic Reflection Prompts via video-based learning system on elementary school students' critical thinking skills. *Computers & Education*, *183*, 104497.https://doi.org/10.1016/j.compedu.2022.104497

[3] Hassan, T. (2022). A global update on covid-19 pandemic: Vaccines and new variants. *Pakistan Journal of Medicine & Dentistry*, 11(1), 89-93.https://doi.org/10.36283/PJMD11-1/015

[4] Donham, C., Barron, H. A., Alkhouri,J. S., Kumarath, M. C., Alejandro, W., Menke, E., & Kranzfelder, P. (2022). I will teach you here or there, I will try to teach you anywhere: perceived supports and barriers for emergency remote teaching during the COVID-19 pandemic.*International Journal of STEM Education*, 9(19), 1-25.https://doi.org/10.1186/s40594-022-00341-3

[5] Temelli, D. (2022). Reflexes of international organizations regarding education in the covid-19 pandemic process and comparing implementations in turkey. *Milli Egitim*, 51(233), 887-909.https://doi.org/10.37669/milliegitim.788444

[7] Olmes, G. L., Zimmermann, J. S. M., Stotz, L., Takacs, F. Z., Hamza, A., Radosa, M. P., Findeklee, S., Solomayer, E. F.,&Radosa, J. C. (2021). Students' attitudes toward digital learning during the covid-19 pandemic: a survey conducted following an online course in gynecology and obstetrics. *Archives of Gynecology and Obstetrics*, 304(4), 957-963.https://doi.org/10.1007/s00404-021-06131-6

[8] Guppy, N., Verpoorten, D., Boud, D., Lin, L., Tai. J., & Bartolic, S. (2022). The post-COVID-19 future of digital learning in higher education: Views from educators, students, and other professionals in six countries. *British Journal of Educational Technology*, 1(1), 1-22.https://doi.org/10.1111/bjet.13212

[9] Adde, D., Amponsah, S., & Gborti, B. J. (2022). Covid-19 pandemic and the shift to digital learning: experiences of students in a community college in ghana. *Community College Journal of Research and Practice*, 46(1), 101-112.https://doi.org/10.1080/10668926.2021.1972364

[10] Poluakan, C., & Katuuk, D. (2021). PIMCA: a new alternativesto physics learning model. *Journal of Physics: Conference Series*, 2165, 1-6.https://doi.org/10.1088/1742-6596/2165/1/012013

[11] Ivanec, T. P. (2022). The lack of academic social interactions and students' learning difficulties during covid-19 faculty lockdowns in Croatia: the mediating role of the perceived sense of life disruption caused by the pandemic and the adjustment to online studying. *Journal Social Science*, 11(42), 1-11.https://doi.org/10.3390/socsci11020042

[12] Vieyra, R., & Himmelsbach, J. (2022). Teachers' disciplinary boundedness in the implementation of integrated computational modeling in physics. *Journal of Science Education and Technology*, 31(2), 153-165.https://doi.org/10.1007/s10956-021-09938-9

[13] Dewantara, D., Sofianto, E. W. N., Misbah, &Munawaroh, D. (2021). Physics e-module: A review and bibliometric analysis. *Journal of Physics: Conference Series*, 2104, 1-7.https://doi.org/10.1088/1742-6596/2104/1/012008

[14] 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), 136-154.https://doi.org/10.3991/ijim.v15i08.20415

[15] Wang, J., Shen, L.,& Zhou, W. (2021). A bibliometric analysis of quantum computing literature: mapping and evidences from Scopus.*Technology Analysis and Strategic Management*, 33(11), 1347-1363.https://doi.org/10.1080/09537325.2021.1963429

[16] Kamaruzzaman, W. M., Nasir, N., Hamidi, N. A., Yusof, N., Shaifudin, M. S., Suhaimi, A. M. A. A. M., Badruddin, M. A., Adnan, A., Nik, W. M. N. W., & Ghazali, M. S. M. (2022). 25 years of progress on plants as corrosion inhibitors through a bibliometric analysis using the Scopus database (1995–2020). *Arabian Journal of Chemistry*, 15(4), 4-19.https://doi.org/10.1016/j.arabjc.2021.103655

[17] Kulkanjanapiban, P., & Silwattananusarn T. (2022). Comparative analysis of Dimensions and Scopus bibliographic data sources: An approach to university research productivity. *International Journal of Electrical and Computer Engineering*, 12(1) 706-720.https://doi.org/10.11591/ijece.v12i1.pp706-720

[18] Putri, C. R., Soleh, S. M., Saregar, A., Anugrah, A.,&Susilowati, N. E. (2021). Bibliometric analysis: Augmented reality-based physics laboratory with VOSviewer software. *Journal of Physics: Conference Series*, 1796, 1-12.https://doi.org/10.1088/1742-6596/1796/1/012056

[19] Nishioka, C., & Farber, M. (2020). Trends of publications' citations and altmetrics based on open access types. Proceedings of the ACM/IEEE Joint Conference on Digital Libraries, 503-

504.https://doi.org/10.1145/3383583.3398584
[20] Soehartono, A. M., Yu, L. G., & Khor, K. A. (2022). Essential signals in publication trends and collaboration patterns in global Research Integrity and Research Ethics (RIRE). *Scientometrics*, 1-11.https://doi.org/10.1007/s11192-022-04400-y
[21] Sousa, M. J., & Rocha, A. (2018). Special section on "emerging trends and challenges in digital learning". *Universal Access in the Information Society*, 17(4), 675-677.https://doi.org/10.1007/s10209-017-0572-6
[22] Zhao, L., Cao, C., Li, Y., & Li, Y. (2022). Determinants of the digital outcome divide in e-learning between rural and urban students: empirical evidence from the covid-19 pandemic based on capital theory. *Computers in Human Behavior*,130(1), 1-15.https://doi.org/10.1016/j.chb.2021.107177
[23] 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 and biomedical engineering*, 17(10), 144-159.https://doi.org/10.3991/ijoe.v17i10.25243
[24] Effendi, D. N., Irwandani, Anggraini, W., Jatmiko, A., Rahmayanti, H., Ichsan, I. Z., & Rahman, M. M. (2021). Bibliometric analysis of scientific literacy using VOS viewer: Analysis of science education. *Journal of Physics: Conference Series*, 1796, 1-10.https://doi.org/10.1088/1742-6596/1796/1/012096
[25] Pristianti, M. C. (2022). Top 100 cited research of confirmatory factor analysis (CFA) in education from 2012 to 2021. *International Journal of Current Educational Research*, 1(1), 68-83.https://doi.org/10.53621/ijocer.v1i1.140
[26] Anderson, J. L., & Barnett, M. (2013). Learning physics with digital game simulations in middle school science. *Journal of Science Education and Technology*, 22(6), 914-926.https://doi.org/10.1007/s10956-013-9438-8
[27] Sengupta, P.,Krinks, K. D., & Clark, D. B. (2015). Learning to deflect: conceptual change in physics during digital gameplay. *Journal of the Learning Sciences*, 24(4), 638-674.http://dx.doi.org/10.1080/10508406.2015.1082912
[28] Melo M. (2018). The 4C/ID-model in physics education: Instructional design of a digital learning environment to teach electrical circuits. *International Journal of Instruction*, 11(1), 103-122.https://doi.org/10.12973/iji.2018.1118a
[29] Euler, E., Prytz, C., & Gregorcic, B. (2020). Never far from shore: Productive patterns in physics students' use of the digital learning environment Algodoo. *Physics Education*, 55(4), 1-8.https://doi.org/10.1088/1361-6552/ab83e7
[30] Sukarno & Widdah, M.E. (2020). The effect of students' metacognition and digital literacy in virtual lectures during the covid-19 pandemic on achievement in the "methods and strategies on physics learning" course. *Jurnal Pendidikan IPA Indonesia*, 9(4), 477-488.https://doi.org/10.15294/jpii.v9i4.25332
[31] Arianto, M. A. & Basthomi, Y. (2021).The authors' research gap strategies in elt research article introductions: does Scopus journal quartile matter?. *Journal of Language and Linguistic Studies*, 17(4), 1743-1759.https://doi.org/10.52462/jlls.127
[32] Engerman, J. A., & Otto, R. F. (2021). The shift to digital: designing for learning from a culturally relevant interactive media perspective. *Educational Technology Research and Development*, 69(1), 301-305.https://doi.org/10.1007/s11423-020-09889-9
[33] Balaton, M., Cavadas, J., Carvalho, P. S., & Lima, J. J. G. (2021).Programming ozobots for teaching astronomy. *Physics Education*, 56(4), 1-8.https://doi.org/10.1088/1361-6552/abfb44
[34] Wongsuwan, W., Huntula, J.,&Liu, C. C. (2022).The interactive computer simulation and learning activity for facilitating students' conceptual understanding on the buoyant force through the CoSci learning platform. *Journal of Physics: Conference Series*, 2145, 1-6.https://doi.org/10.1088/1742-6596/2145/1/012075
[35] Susilowati, N. E., Samsudin, A., & Muslim. (2021).What do physics teachers need? A need analysis of interactive multimedia to train creative thinking in static fluid. *Journal of Physics: Conference Series*, 2098, 1-6.https://doi.org/10.1088/1742-6596/2098/1/012029

Digital Learning Research in ~~T~~the Last 30 Years: Important Role of Interactive Learning in Physics

Binar Kurnia Prahani[1], Mila Candra Pristianti[1], Budi Jatmiko[1], Tan Amelia[2], Firmanul Catur Wibowo[3]

[1]*Universitas Negeri Surabaya, Surabaya, Indonesia*
[2]*Universitas Dinamika,Surabaya, Indonesia*
[3] *Universitas Negeri Jakarta,Jakarta, Indonesia*
binarprahani@unesa.ac.id

Abstract **– The aim is to analyze top 100 highest citations of digital learning research topics and the important role of interactive learning in physics ~~learning~~ in 1992-2021. This study uses bibliometric analysis and literature review. The trend of digital learning topics is increasing~~e~~ steadily, from 2014 to 2021. Digital learning shows an excellent contribution to physics learning. The important role of interactive learning in physics is~~are~~ to improve student learning outcomes, deepen understanding and make learning more interesting. More intensively, further research can be carried out by comparing other learning systems applied in physics learning.**

Keywords **– ~~B~~bibliometric, ~~D~~digital ~~L~~learning, ~~E~~education, ~~P~~physics ~~L~~learning**

1. Introduction

Various kinds of learning systems have been applied according to surrounding conditions, the example~~s~~ is~~are~~ digital learning. The development of learning systems must pay attention to the ease of adaptation and transformation [1], [2]. Learning development can be done by combining organizational learning theory and general systems theory.

There are many impacts of the covid-19 pandemic, one of which is in the world of education. One of the updates on October 10, 2021, the entire country has reported 219 million cases with 4.55 million deaths [3]. With the danger that threatens, many countries are trying to make learning sustainable [4]. Efforts are made to organize healthy learning during the covid-19 pandemic crisis [5]. The covid-19 outbreak caused the closure of schools and colleges, so that educational institutions designed more flexible. Research conducted by Leonhard [6], Neil [7], and David [8] concluded that during the covid-19 pandemic, student responses showed good acceptance of digital learning. Students accepted and adapted easily to digital technology during the covid-19 pandemic.

Physics learning is closely related to natural phenomena and experimental activities. The flexibility~~le~~ of physics learning can be done using~~e~~ digital technology or without it [9]. By learning physics through digital learning students are challenged to be more independent, must ~~be~~ easily ~~to~~ adapt and be willing to learn. However, there are shortcomings in the implementation of digital learning, namely some places have limited access to digital media~~,~~ and potential dependence on digital technology [10]. Mentoring and supervision by physics teachers will determine the success of digital learning [11].

From the existing studies, there is still no discussion that shows the contribution of digital learning in physics learning and the important role of interactive learning in physics. Some studies tend to discuss digital learning, but to show the right data

DOI: 10.18421/TEMxx-xx
https://doi.org/10.18421/TEMxx-xx

Corresponding author: Binar Kurnia Prahani, Universitas Negeri Surabaya, Indonesia

Email: binarprahani@unesa.ac.id

Received: -----.
Accepted: -----.
Published: -----.

regarding the analysis, bibliometric studies and literature reviews are needed. Bibliometric analysis is a method to provide knowledge regarding the growth and flow of literature in a particular publication field [12]. This bibliometric study uses empirical data to track existing publications [13]. This study can analyze the distribution of manuscripts sorted by country, source, year and more [14].

This research was carried out ~~W~~with an explanation of the importance of digital learning as well as the existing shortcomings~~, this research was carried out~~. The aim is to analyze top 100 highest citations of digital learning research topics, and the important role of interactive learning in physics from 1992 to 2021. For analysis are used~~ing~~ bibliometrics and also literature review. The objective research included:

1. Analysis~~ze~~ of the trend of digital learning publications from the last thirty years.
2. Identifying the most widely used keywords, the country and author that contribute the most to the publication of digital learning in the last thirty years.
3. Identifying document types and source titles for digital learning from the last thirty years.
4. Identifying the year wise distribution of the top 100 cited digital learning publications from the last thirty years.
5. Identifying the contribution of digital learning in physics learning over the last thirty years.
6. Identifying the advantages and disadvantages of digital learning.
7. Analysis~~ze~~ of the important role of interactive learning in physics.

2. Methods

This study uses bibliometric analysis and literature review. The data used in this study were taken from Scopus. Scopus is well-known for its largest database of publications in various fields including academics [15], [16]. Data from Scopus can be adjusted according to the needs of the year, title, country, keywords, and so on [17]. In addition, this study uses a literature review from previous studies as a reinforcement of research data.

Research data was taken on April 1, 2022. The data in Scopus is selected based on the keywords you want to search for. In this study, the keyword selection stage was carried out twice, the first regarding digital learning. Furthermore, the second keywords are connected with physics learning to find the contribution of digital learning, ~~for~~more details can be seen in Figure 1. The data was obtained in the form of .csv which was then analyzed using Microsoft excel and .ris which was analyzed using VOSViewer [18].

b

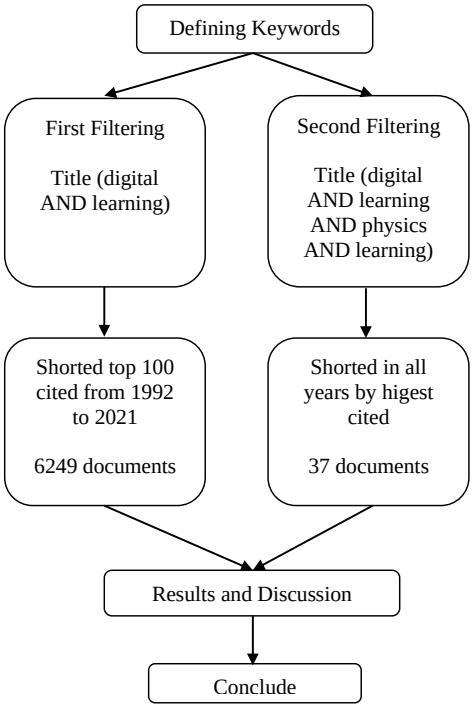

Figure 1. Flowchart for the keyword filtering

3. Results and ~~D~~discussion

3.1 Publication ~~T~~trend in the ~~L~~last 30 ~~Y~~years

From Figure 2., we can see the trend of publications related to digital learning. The trend of publication is an important aspect to pay attention to and follow up [19]. Considering that publications must be in accordance with current conditions, which mean the development of a topic is determined from the trend of publications each year [20].

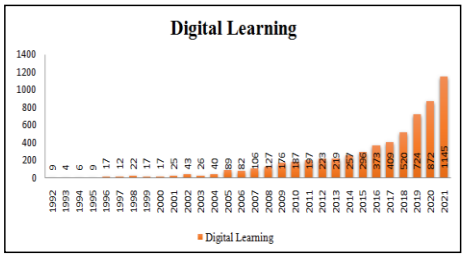

Figure 2. Digital learning publication trends

The highest digital learning publication was in 2021 with 1145 documents and the lowest in 1993 with 4 documents. Digital learning publications began to increase steadily, from 2014 to 2021. The highest increase occurred in 2021 with as many as 273 documents from 2020. The researchers tend to be interested in raising the topic of digital learning [21]. This is in line with the fact that the majority of education in the world has used digital learning due to the emergence of the Covid-19 pandemic [22]. So that research related to digital learning has high potential for future research.

3.2 Visualization of ~~T~~the ~~M~~most ~~U~~used ~~K~~keywords, ~~T~~top ~~C~~countries and ~~T~~top ~~A~~authors ~~W~~who ~~C~~contributed the ~~M~~most

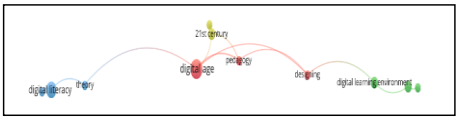

Figure 3. The keywords visualization of digital learning

Figure 3. shows the keyword visualization using VOSViewer. Keywords can describe the subject matter in a publication [23]. For digital learning topics, the most commonly used keyword is "digital age" which has 8 occurrences and "digital literacy" has 6 occurrences.

Table 1. Comparison of the top 10 countries with the most publications in the last thirty years

Top 10 countries	Publications
United States	1,359
United Kingdom	460
China	422
Germany	347
Australia	319
Taiwan	306
Spain	281
Indonesia	221
Canada	208
India	187

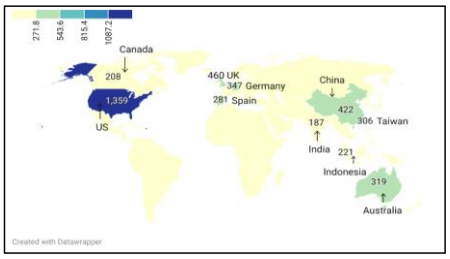

Figure 4. Top 10 Countries with publications about digital learning

From Table 1. and Figure 4., it can be concluded that the United States has the highest contribution over the last thirty years both on the topic of digital learning. There are five countries that consistently occupy the top 10 on all publication topics related to digital learning including the United States, China, United Kingdom, Australia and Spain. To identify the author who has the most publications on each topic of digital learning, we were using VOS viewer and Microsoft Excel analysis. The results of the Microsoft Excel analysis are shown in Table 2.

Table 2. The top 10 author with the highest citations in the last thirty years

Author	Total Citations	Country
M. Papastergiou	1,880	Greece
K. Kiili	1,978	Finland
C.M. Greenhow	2,509	United States
A.R. Janowczyk	1,269	United States
D.B. Clark	3,069	Canada
A. Madabhushi	14,845*	United States
B. Gros	660	Spain
S. Erhel	429	France
A. Sadik	367	Egypt
B.Q. Huynh	590	United States

Table 2. shows the top 10 authors from the highest citations for the topic of digital learning, M. Papastergiou from Greece. Meanwhile, the highest total citation was owned by A. Madabhushi ~~came~~ from the United States. To find out who the author on the topic of digital learning is the most contributing and connected is using VOSViewer. With VOSViewer we can identify the classification of top authors [24]. The grouping and connection of each author is indicated by the presence of clusters [25]. The first results of the digital learning topic are~~is~~ divided into 3 clusters, namely red (n=5), green (4), blue (n=2). H. Beetham is the main author because he has 3 documents with 2 total links strength which is more than any other author.

3.3 The ~~D~~document ~~T~~types and ~~S~~source ~~T~~titles of ~~T~~top 100 ~~H~~highest ~~C~~cited ~~P~~publications in the ~~L~~last 30 ~~Y~~years

Table 3. The document types of top 100 highest cited digital learning publication in the last 30 years

Document Type	Freq-uency	Cited	Mean	Med-ian	SD
Article	81*	14206*	175.3	125	160.8*
Conference paper	7	808	115.4	95	47.2
Review	4	810	202.5*	209.5*	96.6
Note	0	0	0	0	-

Document Type	Freq-uency	Cited	Mean	Med-ian	SD
Book	7	1011	144.4	129	63.1
Editorial	1	376	376	376	-

Table 3. shows ~~on~~ digital learning topics, ~~the~~ most of the publications are in the form of articles (n=81). Digital learning has been ~~the total~~totally cited ~~is~~ 14,206. The standard deviation is quite high, namely digital learning (n=160.8).

Table 4. The source titles of top 100 highest cited publication in the last 30 years

Source Title	TD	TC
Computers and Education	13	2983
Educational Technology and Society	4	415
Journal of Computer Assisted Learning	3	565
Journal of Research on Technology in Education	3	530
Language and Learning in the Digital Age	3	468
Geoderma	3	386
ReCALL	3	325
Internet and Higher Education	2	1008
Rethinking Pedagogy for a Digital Age: Designing and Delivering E-Learning	2	343
Learning, Media and Technology	2	264
TD = Total Documents TC = Total Citations		

Table 4. shows that the source titles of digital learning are varied. For the highest source title digital learning namely Computers and Education (n=13 documents). The highest total citation is 2,983 namely source title is Computers and Education.

3.4 The ~~Y~~year ~~W~~wise ~~D~~distribution of ~~T~~top 100 ~~H~~highest ~~C~~cited ~~P~~publications in the ~~L~~last 30 ~~Y~~years

Table 5. contains information on the distribution of the top 100 cited publications on the topics of digital learning. The range of data used is from 1992 to 2021.

Table 5. The year wise distribution of top 100 highest cited publications in the last 30 years

Year	Citable Year	Digital Learning			
		TC	TD	ACPP	ACPPY
1992	30	0	0	0	0
1993	29	0	0	0	0
1994	28	0	0	0	0
1995	27	215	2	107.5	3.9
1996	26	0	0	0	0
1997	25	0	0	0	0
1998	24	0	0	0	0
1999	23	0	0	0	0
2000	22	0	0	0	0
2001	21	420	2	210	10
2002	20	0	0	0	0
2003	19	0	0	0	0
2004	18	454	2	227	12.6
2005	17	1237	4	309.2*	18.2
2006	16	270	2	135	8.4
2007	15	891	5	178.2	11.8
2008	14	869	5	173.8	12.4
2009	13	2282	7	326	25.1
2010	12	421	3	140.3	11.6
2011	11	932	7	133.1	12.1
2012	10	1327	10	132.7	13.3
2013	9	1199	7	171.3	19
2014	8	894	8	111.7	13.9
2015	7	443	4	110.7	15.8
2016	6	2699*	11*	245.4	40.9
2017	5	567	4	141.7	28.4
2018	4	881	6	146.8	36.7
2019	3	884	9	98.2	32.7
2020	2	326	2	163	81.5*
2021	1	0	0	0	0
*The Highest Number					

This information can be used to see in what year the top 100 cited publications were produced on the topic. From this study it was found that the highest year is 2016 (n=11 documents). In addition, from this study it was found that the highest year is 2016 (n=2,699 citations). The highest average citation per paper per year in 2020 is 81,5.

3.5 Literature ~~R~~review of ~~D~~digital ~~L~~learning to ~~P~~physics ~~L~~learning

Table 6. contains the results of the literature review by taking into account the quartiles, citations, and findings to provide recommendations regarding the selected paper.

Table 6. Top 5 highest cited paper showinged contribution of digital learning to physics learning

Author	SJR	Citation	Findings
Anderson, J. L., & Barnett, M. [26]	1,03 (Q1)	46	Digital learning with game simulations has a positive impact on the learning outcomes of junior high school students in physics learning.
Sengupta, P., Krinks, K. D., & Clark, D. B. [27]	4,06 (Q1)	22	The results of the study show that the combination of using digital learning fosters student physics learning motivation.
Melo, M. [28]	0,54 (Q2)	4	The use of digital learning 4C/ID model in physics content to students has a positive impact on learning outcomes.
Euler, E., Prytz, C., & Gregorcic, B. [29]	0,34 (Q3)	1	Digital learning using the Algodoo application gives students the opportunity to explore physics learning materials for free and able to attract students' attention in learning.

Author	SJR	Citation	Findings
Sukarno & Widdah, M.E. [30]	0,49 (Q2)	1	Students' metacognitive and digital literacy skills increase in physics learning.

The ranking system of reputable journals based on the subject or category of the related journal field is also called quartiles [31]. From these results, it can be seen that the topic of digital learning has the highest citation ~~is~~ 46, thus, research related to digital learning in physics will have a lot of potentials, and its novelty will be quite high. Digital learning tends to take advantage of interactive learning applications to increase student motivation and learning outcomes [32].

3.6 Advantage and ~~D~~disadvantage of ~~D~~digital ~~L~~learning to ~~P~~physics ~~L~~learning

Table 7. Discussion about digital learning

Discussion	Digital Learning
Meaning	Learning media that can be done digitally without having to wait for internet access to start.
Characteristics	• Some digital learning can be accessed without internet • Not tied to face-to-face or non-face-to-face learning • More towards the learning media
Advantage	Can be used in various places, can trigger students to think creatively and innovatively
Disadvantage	Can lead to dependence on digital tools so that it can cause laziness in students

From ~~T~~table 7., broadly speaking, it can be concluded that digital learning has advantages in flexibility and types of media that utilize sophisticated digital tools. While the disadvantages have an impact on students' lifestyles which can become dependent on digital learning media. The digital learning is a learning process that requires internet access, while digital learning does not always require internet access.

3.7 Analysis~~z~~e of the ~~I~~important ~~R~~role of ~~I~~interactive ~~L~~learning in ~~P~~physics ~~B~~based on ~~D~~digital ~~L~~learning ~~R~~research

Learning physics still tends to be difficult for most students to understand. Physics learning needs to be set more interactively for students. The use of interactive learning media can be integrated using a combination of video, graphics, text, and sound. Digital learning by applying interactive virtual reality can deepen students' understanding of physics material. In addition, through good quality worksheets in digital learning can be improved the students' critical thinking skills in learning physics. Practical activities can play an important role in engaging students with the world of science, especially when using digital tools. So, it can be concluded that interactive learning can improve student learning outcomes [33].

The majority of students in the 21st century is proficient in advanced technology and are adaptable. For example, the use of interactive modules is also very important to apply because, according to research [34], digital learning of physics with interactive modules shows compatibility and a positive impact. Since the last three years, the world has been affected by the pandemic, so academic units must also think about effective learning methods that can still improve student achievement. Therefore, interactive learning in physics is starting to be more widely applied. One of them is by using interactive multimedia, which is able to improve students' understanding of concepts [35]. Interactive learning plays an important role in deepening the concept of physics and making the learning atmosphere more interesting even through digital learning.

4. Conclusion

Research results analysis using bibliometric studies and literature reviews related to digital learning research get several conclusions. The conclusion is that the trend of digital learning topics is increased steadily, from 2014 to 2021. The most commonly used keywords are digital age, and digital literacy. The United States (US) has made the highest contribution over the last thirty years on digital learning. The author with the highest citation on digital learning is M. Papastergiou from Greece. The type of document that is often published in the article. The highest source titles digital learning~~, namely~~ is the paper *Computers and Education*. The highest average citation per paper per year is in 2020 where digital learning (n=81,5). The digital learning topics contribute to learning physics. From the explanation above, the future research related to digital learning in physics will have a lot of potentials, and its novelty will be quite high. The important role of interactive learning in physics is to improve student learning outcomes, train critical thinking skills, deepen understanding of concepts and make learning more interesting. The advantages in flexibility and types of media that utilize sophisticated digital tools. While the disadvantages have an impact on students' lifestyles which can become dependent on digital learning media and because it's using the internet network, which requires costs and a strong signal because not all areas have a strong network connection.

The implication of this research is to show the trend of publication of digital learning topics so that future researchers can show more benefits related to these topics. With this article, researchers can find out

Formatted: Font: (Default) Times New Roman, Italic, Condensed by 0,05 pt

the strengths and weaknesses of digital learning topic and can find updates for future research. The limitation of the study is that some research results at Scopus are limited to full access. More intensively, further research can be carried out by comparing other learning systems applied in physics learning.

5. Acknowledgement

The author's gratitude goes to the *Direktorat Jenderal Pendidikan Tinggi, Riset, dan Teknologi; Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, Indonesia* who has supported funding in *Penelitian Dasar Unggulan Perguruan Tinggi* - DRTPM 2022 [Contract Number: 29551/UN38.9/LK.04.00/2022].

References

[1] Dias Canedo E., Aymoré Martins V., Coelho Ribeiro V., dos Reis V.E., Carvalho Chaves L.A., Machado Gravina R., Alberto Moreira Dias F., Lopes de Mendonça F.L., Orozco A.L.S., Balaniuk R., de Sousa R.T Jr. (2021). Development and Evaluation of an Intelligence and Learning System in Jurisprudence Text Mining in the Field of Competition Defense. *Applied Sciences*, 11(23), 11365.https://doi.org/10.3390/app112311365

[2] Hsu, F. H., Lin, I. H., Yeh, H. C., & Chen, N. S. (2022). Effect of Socratic Reflection Prompts via video-based learning system on elementary school students' critical thinking skills. *Computers & Education*, *183*, 104497.https://doi.org/10.1016/j.compedu.2022.104497

[3] Hassan, T. (2022). A global update on covid-19 pandemic: Vaccines and new variants. *Pakistan Journal of Medicine & Dentistry*, 11(1), 89-93.https://doi.org/10.36283/PJMD11-1/015

[4] Donham, C., Barron, H. A., Alkhouri,J. S., Kumarath, M. C., Alejandro, W., Menke, E., & Kranzfelder, P. (2022). I will teach you here or there, I will try to teach you anywhere: perceived supports and barriers for emergency remote teaching during the COVID-19 pandemic.*International Journal of STEM Education*, 9(19), 1-25.https://doi.org/10.1186/s40594-022-00341-3

[5] Temelli, D. (2022). Reflexes of international organizations regarding education in the covid-19 pandemic process and comparing implementations in turkey. *Milli Egitim*, 51(233), 887-909.https://doi.org/10.37669/milliegitim.788444

[7] Olmes, G. L., Zimmermann, J. S. M., Stotz, L., Takacs, F. Z., Hamza, A., Radosa, M. P., Findeklee, S., Solomayer, E. F.,&Radosa, J. C. (2021). Students' attitudes toward digital learning during the covid-19 pandemic: a survey conducted following an online course in gynecology and obstetrics. *Archives of Gynecology and Obstetrics*, 304(4), 957-963.https://doi.org/10.1007/s00404-021-06131-6

[8] Guppy, N., Verpoorten, D., Boud, D., Lin, L., Tai. J., & Bartolic, S. (2022). The post-COVID-19 future of digital learning in higher education: Views from educators, students, and other professionals in six countries. *British Journal of Educational Technology*, 1(1), 1-22.https://doi.org/10.1111/bjet.13212

[9] Adde, D., Amponsah, S., & Gborti, B. J. (2022). Covid-19 pandemic and the shift to digital learning: experiences of students in a community college in ghana. *Community College Journal of Research and Practice*, 46(1), 101-112.https://doi.org/10.1080/10668926.2021.1972364

[10] Poluakan, C., & Katuuk, D. (2021). PIMCA: a new alternativesto physics learning model. *Journal of Physics: Conference Series*, 2165, 1-6.https://doi.org/10.1088/1742-6596/2165/1/012013

[11] Ivanec, T. P. (2022). The lack of academic social interactions and students' learning difficulties during covid-19 faculty lockdowns in Croatia: the mediating role of the perceived sense of life disruption caused by the pandemic and the adjustment to online studying. *Journal Social Science*, 11(42), 1-11.https://doi.org/10.3390/socsci11020042

[12] Vieyra, R., & Himmelsbach, J. (2022). Teachers' disciplinary boundedness in the implementation of integrated computational modeling in physics. *Journal of Science Education and Technology*, 31(2), 153-165.https://doi.org/10.1007/s10956-021-09938-9

[13] Dewantara, D., Sofianto, E. W. N., Misbah, &Munawaroh, D. (2021). Physics e-module: A review and bibliometric analysis. *Journal of Physics: Conference Series*, 2104, 1-7.https://doi.org/10.1088/1742-6596/2104/1/012008

[14] 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), 136-154.https://doi.org/10.3991/ijim.v15i08.20415

[15] Wang, J., Shen, L.,& Zhou, W. (2021). A bibliometric analysis of quantum computing literature: mapping and evidences from Scopus.*Technology Analysis and Strategic Management*, 33(11), 1347-1363.https://doi.org/10.1080/09537325.2021.1963429

[16] Kamaruzzaman, W. M., Nasir, N., Hamidi, N. A., Yusof, N., Shaifudin, M. S., Suhaimi, A. M. A. A. M., Badruddin, M. A., Adnan, A., Nik, W. M. N. W., & Ghazali, M. S. M. (2022). 25 years of progress on plants as corrosion inhibitors through a bibliometric analysis using the Scopus database (1995–2020). *Arabian Journal of Chemistry*, 15(4), 4-19.https://doi.org/10.1016/j.arabjc.2021.103655

[17] Kulkanjanapiban, P., & Silwattananusarn T. (2022). Comparative analysis of Dimensions and Scopus bibliographic data sources: An approach to university research productivity. *International Journal of Electrical and Computer Engineering*, 12(1) 706-720.https://doi.org/10.11591/ijece.v12i1.pp706-720

[18] Putri, C. R., Soleh, S. M., Saregar, A., Anugrah, A.,&Susilowati, N. E. (2021). Bibliometric analysis: Augmented reality-based physics laboratory with VOSviewer software. *Journal of Physics: Conference Series*, 1796, 1-12.https://doi.org/10.1088/1742-6596/1796/1/012056
[19] Nishioka, C., & Farber, M. (2020). Trends of publications' citations and altmetrics based on open access types. Proceedings of the ACM/IEEE Joint Conference on Digital Libraries, 503-504.https://doi.org/10.1145/3383583.3398584
[20] Soehartono, A. M., Yu, L. G., & Khor, K. A. (2022). Essential signals in publication trends and collaboration patterns in global Research Integrity and Research Ethics (RIRE). *Scientometrics*, 1-11.https://doi.org/10.1007/s11192-022-04400-y
[21] Sousa, M. J., & Rocha, A. (2018). Special section on "emerging trends and challenges in digital learning". *Universal Access in the Information Society*, 17(4), 675-677.https://doi.org/10.1007/s10209-017-0572-6
[22] Zhao, L., Cao, C., Li, Y., & Li, Y. (2022). Determinants of the digital outcome divide in e-learning between rural and urban students: empirical evidence from the covid-19 pandemic based on capital theory. *Computers in Human Behavior*,130(1), 1-15.https://doi.org/10.1016/j.chb.2021.107177
[23] 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 and biomedical engineering*, 17(10), 144-159.https://doi.org/10.3991/ijoe.v17i10.25243
[24] Effendi, D. N., Irwandani, Anggraini, W., Jatmiko, A., Rahmayanti, H., Ichsan, I. Z., & Rahman, M. M. (2021). Bibliometric analysis of scientific literacy using VOS viewer: Analysis of science education. *Journal of Physics: Conference Series*, 1796, 1-10.https://doi.org/10.1088/1742-6596/1796/1/012096
[25] Pristianti, M. C. (2022). Top 100 cited research of confirmatory factor analysis (CFA) in education from 2012 to 2021. *International Journal of Current Educational Research*, 1(1), 68-83.https://doi.org/10.53621/ijocer.v1i1.140
[26] Anderson, J. L., & Barnett, M. (2013). Learning physics with digital game simulations in middle school science. *Journal of Science Education and Technology*, 22(6), 914-926.https://doi.org/10.1007/s10956-013-9438-8
[27] Sengupta, P.,Krinks, K. D., & Clark, D. B. (2015). Learning to deflect: conceptual change in physics during digital gameplay. *Journal of the Learning Sciences*, 24(4), 638-674.http://dx.doi.org/10.1080/10508406.2015.1082912
[28] Melo M. (2018). The 4C/ID-model in physics education: Instructional design of a digital learning environment to teach electrical circuits. *International Journal of Instruction*, 11(1), 103-122.https://doi.org/10.12973/iji.2018.1118a
[29] Euler, E., Prytz, C., & Gregorcic, B. (2020). Never far from shore: Productive patterns in physics students' use of the digital learning environment Algodoo. *Physics Education*, 55(4), 1-8.https://doi.org/10.1088/1361-6552/ab83e7
[30] Sukarno & Widdah, M.E. (2020). The effect of students' metacognition and digital literacy in virtual lectures during the covid-19 pandemic on achievement in the "methods and strategies on physics learning" course. *Jurnal Pendidikan IPA Indonesia*, 9(4), 477-488.https://doi.org/10.15294/jpii.v9i4.25332
[31] Arianto, M. A. & Basthomi, Y. (2021).The authors' research gap strategies in elt research article introductions: does Scopus journal quartile matter?. *Journal of Language and Linguistic Studies*, 17(4), 1743-1759.https://doi.org/10.52462/jlls.127
[32] Engerman, J. A., & Otto, R. F. (2021). The shift to digital: designing for learning from a culturally relevant interactive media perspective. *Educational Technology Research and Development*, 69(1), 301-305.https://doi.org/10.1007/s11423-020-09889-9
[33] Balaton, M., Cavadas, J., Carvalho, P. S., & Lima, J. J. G. (2021).Programming ozobots for teaching astronomy. *Physics Education*, 56(4), 1-8.https://doi.org/10.1088/1361-6552/abfb44
[34] Wongsuwan, W., Huntula, J.,&Liu, C. C. (2022).The interactive computer simulation and learning activity for facilitating students' conceptual understanding on the buoyant force through the CoSci learning platform. *Journal of Physics: Conference Series*, 2145, 1-6.https://doi.org/10.1088/1742-6596/2145/1/012075
[35] Susilowati, N. E., Samsudin, A., & Muslim. (2021).What do physics teachers need? A need analysis of interactive multimedia to train creative thinking in static fluid. *Journal of Physics: Conference Series*, 2098, 1-6.https://doi.org/10.1088/1742-6596/2098/1/012029

Digital Learning Research in the Last 30 Years: Important Role of Interactive Learning in Physics

Binar Kurnia Prahani[1], Mila Candra Pristianti[1], Budi Jatmiko[1], Tan Amelia[2], Firmanul Catur Wibowo[3]

[1]*Universitas Negeri Surabaya, Surabaya, Indonesia*
[2]*Universitas Dinamika,Surabaya, Indonesia*
[3] *Universitas Negeri Jakarta,Jakarta, Indonesia*
binarprahani@unesa.ac.id

***Abstract* – The aim is to analyze top 100 highest citations of digital learning research topics and the important role of interactive learning in physics in 1992-2021. This study uses bibliometric analysis and literature review. The trend of digital learning topics is increasing steadily, from 2014 to 2021. Digital learning shows an excellent contribution to physics learning. The important role of interactive learning in physics is to improve student learning outcomes, deepen understanding and make learning more interesting. More intensively, further research can be carried out by comparing other learning systems applied in physics learning.**

***Keywords* – bibliometric, digital learning, education, physics learning**

1. Introduction

Various kinds of learning systems have been applied according to surrounding conditions, the example is digital learning. The development of learning systems must pay attention to the ease of adaptation and transformation [1], [2]. Learning development can be done by combining organizational learning theory and general systems theory.

There are many impacts of the covid-19 pandemic, one of which is in the world of education. One of the updates on October 10, 2021, the entire country has reported 219 million cases with 4.55 million deaths [3]. With the danger that threatens, many countries are trying to make learning sustainable [4]. Efforts are made to organize healthy learning during the covid-19 pandemic crisis [5]. The covid-19 outbreak caused the closure of schools and colleges, so that educational institutions designed more flexible. Research conducted by Leonhard [6], Neil [7], and David [8] concluded that during the covid-19 pandemic, student responses showed good acceptance of digital learning. Students accepted and adapted easily to digital technology during the covid-19 pandemic.

Physics learning is closely related to natural phenomena and experimental activities. The flexibility of physics learning can be done using digital technology or without it [9]. By learning physics through digital learning students are challenged to be more independent, must easily adapt and be willing to learn. However, there are shortcomings in the implementation of digital learning, namely some places have limited access to digital media and potential dependence on digital technology [10]. Mentoring and supervision by physics teachers will determine the success of digital learning [11].

From the existing studies, there is still no discussion that shows the contribution of digital learning in physics learning and the important role of interactive learning in physics. Some studies tend to discuss digital learning, but to show the right data

Commented [P1]: Vague. Does not correspond to the context. Consider paraphrasing.

Commented [P2]: The thought is not finished.

DOI: 10.18421/TEMxx-xx
https://doi.org/10.18421/TEMxx-xx

Corresponding author: Binar Kurnia Prahani, Universitas Negeri Surabaya, Indonesia

Email: binarprahani@unesa.ac.id

Received: -----.
Accepted: -----.
Published: -----.

regarding the analysis, bibliometric studies and literature reviews are needed. Bibliometric analysis is a method to provide knowledge regarding the growth and flow of literature in a particular publication field [12]. This bibliometric study uses empirical data to track existing publications [13]. This study can analyze the distribution of manuscripts sorted by country, source, year and more [14].

This research was carried out with an explanation of the importance of digital learning as well as the existing shortcomings. The aim is to analyze top 100 highest citations of digital learning research topics, and the important role of interactive learning in physics from 1992 to 2021. For analysis are used bibliometrics and also literature review. The objective research included:

1. Analysis of the trend of digital learning publications from the last thirty years.
2. Identifying the most widely used keywords, the country and author that contribute the most to the publication of digital learning in the last thirty years.
3. Identifying document types and source titles for digital learning from the last thirty years.
4. Identifying the year wise distribution of the top 100 cited digital learning publications from the last thirty years.
5. Identifying the contribution of digital learning in physics learning over the last thirty years.
6. Identifying the advantages and disadvantages of digital learning.
7. Analysis of the important role of interactive learning in physics.

2. Methods

This study uses bibliometric analysis and literature review. The data used in this study were taken from Scopus. Scopus is well-known for its largest database of publications in various fields including academics [15], [16]. Data from Scopus can be adjusted according to the needs of the year, title, country, keywords, and so on [17]. In addition, this study uses a literature review from previous studies as a reinforcement of research data.

Research data was taken on April 1, 2022. The data in Scopus is selected based on the keywords you want to search for. In this study, the keyword selection stage was carried out twice, the first regarding digital learning. Furthermore, the second keywords are connected with physics learning to find the contribution of digital learning, more details can be seen in Figure 1. The data was obtained in the form of .csv which was then analyzed using Microsoft excel and .ris which was analyzed using VOSViewer [18].

b

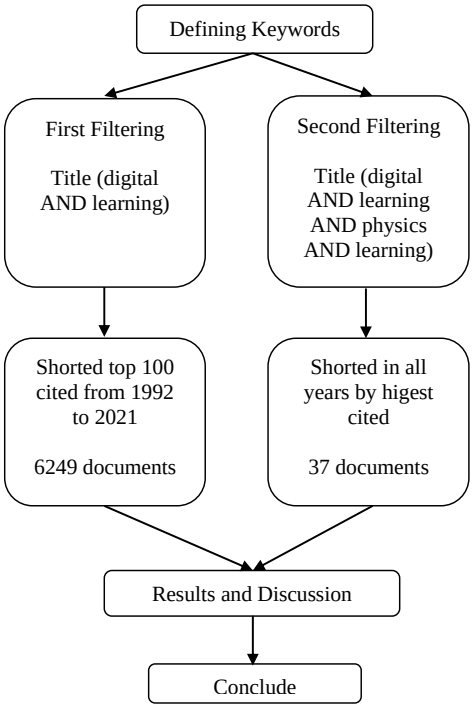

Figure 1. Flowchart for the keyword filtering

3. Results and discussion

3.1 Publication trend in the last 30 years

From Figure 2., we can see the trend of publications related to digital learning. The trend of publication is an important aspect to pay attention to and follow up [19]. Considering that publications must be in accordance with current conditions, which mean the development of a topic is determined from the trend of publications each year [20].

Commented [P3]: ?

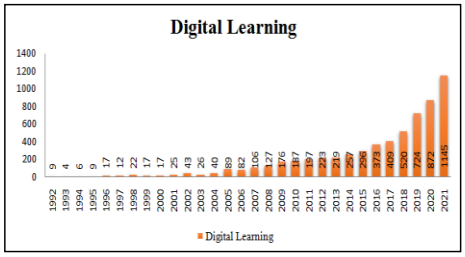

Figure 2. Digital learning publication trends

The highest digital learning publication was in 2021 with 1145 documents and the lowest in 1993 with 4 documents. Digital learning publications began to increase steadily, from 2014 to 2021. The highest increase occurred in 2021 with as many as 273 documents from 2020. The researchers tend to be interested in raising the topic of digital learning [21]. This is in line with the fact that the majority of education in the world has used digital learning due to the emergence of the Covid-19 pandemic [22]. So that research related to digital learning has high potential for future research.

3.2 Visualization of the most used keywords, top countries and top authors who contributed the most

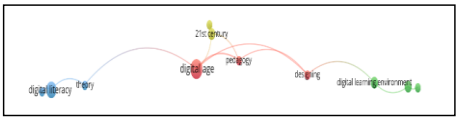

Figure 3. The keywords visualization of digital learning

Figure 3. shows the keyword visualization using VOSViewer. Keywords can describe the subject matter in a publication [23]. For digital learning topics, the most commonly used keyword is "digital age" which has 8 occurrences and "digital literacy" has 6 occurrences.

Table 1. Comparison of the top 10 countries with the most publications in the last thirty years

Top 10 countries	Publications
United States	1,359
United Kingdom	460
China	422
Germany	347
Australia	319
Taiwan	306
Spain	281
Indonesia	221
Canada	208
India	187

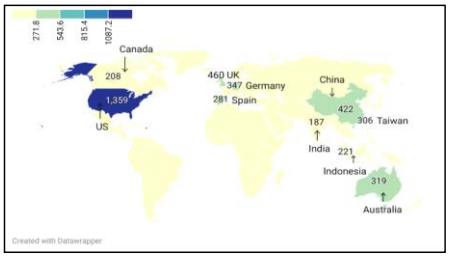

Figure 4. Top 10 Countries with publications about digital learning

From Table 1. and Figure 4., it can be concluded that the United States has the highest contribution over the last thirty years both on the topic of digital learning. There are five countries that consistently occupy the top 10 on all publication topics related to digital learning including the United States, China, United Kingdom, Australia and Spain. To identify the author who has the most publications on each topic of digital learning, we were using VOS viewer and Microsoft Excel analysis. The results of the Microsoft Excel analysis are shown in Table 2.

Table 2. The top 10 author with the highest citations in the last thirty years

Author	Total Citations	Country
M. Papastergiou	1,880	Greece
K. Kiili	1,978	Finland
C.M. Greenhow	2,509	United States
A.R. Janowczyk	1,269	United States
D.B. Clark	3,069	Canada
A. Madabhushi	14,845*	United States
B. Gros	660	Spain
S. Erhel	429	France
A. Sadik	367	Egypt
B.Q. Huynh	590	United States

Table 2. shows the top 10 authors from the highest citations for the topic of digital learning, M. Papastergiou from Greece. Meanwhile, the highest total citation was owned by A. Madabhushi from the United States. To find out who the author on the topic of digital learning is the most contributing and connected is using VOSViewer. With VOSViewer we can identify the classification of top authors [24]. The grouping and connection of each author is indicated by the presence of clusters [25]. The first results of the digital learning topic are divided into 3 clusters, namely red (n=5), green (4), blue (n=2). H. Beetham is the main author because he has 3 documents with 2 total links strength which is more than any other author.

3.3 The document types and source titles of top 100 highest cited publications in the last 30 years

Table 3. The document types of top 100 highest cited digital learning publication in the last 30 years

Document Type	Freq-uency	Cited	Mean	Med-ian	SD
Article	81*	14206*	175.3	125	160.8*
Conference paper	7	808	115.4	95	47.2
Review	4	810	202.5*	209.5*	96.6
Note	0	0	0	0	-
Book	7	1011	144.4	129	63.1
Editorial	1	376	376	376	-

Commented [P4]: Vague.

Commented [P5]: Vague. Consider paraphrasing.

Table 3. shows digital learning topics, most of the publications are in the form of articles (n=81). Digital learning has been totally cited 14,206. The standard deviation is quite high, namely digital learning (n=160.8).

Table 4. The source titles of top 100 highest cited publication in the last 30 years

Source Title	TD	TC
Computers and Education	13	2983
Educational Technology and Society	4	415
Journal of Computer Assisted Learning	3	565
Journal of Research on Technology in Education	3	530
Language and Learning in the Digital Age	3	468
Geoderma	3	386
ReCALL	3	325
Internet and Higher Education	2	1008
Rethinking Pedagogy for a Digital Age: Designing and Delivering E-Learning	2	343
Learning, Media and Technology	2	264
TD = Total Documents TC = Total Citations		

Table 4. shows that the source titles of digital learning are varied. For the highest source title digital learning namely Computers and Education (n=13 documents). The highest total citation is 2,983 namely source title is Computers and Education.

3.4 The year wise distribution of top 100 highest cited publications in the last 30 years

Table 5. contains information on the distribution of the top 100 cited publications on the topics of digital learning. The range of data used is from 1992 to 2021.

Table 5. The year wise distribution of top 100 highest cited publications in the last 30 years

Year	Citable Year	Digital Learning			
		TC	TD	ACPP	ACPPY
1992	30	0	0	0	0
1993	29	0	0	0	0
1994	28	0	0	0	0
1995	27	215	2	107.5	3.9
1996	26	0	0	0	0
1997	25	0	0	0	0
1998	24	0	0	0	0
1999	23	0	0	0	0
2000	22	0	0	0	0
2001	21	420	2	210	10
2002	20	0	0	0	0
2003	19	0	0	0	0
2004	18	454	2	227	12.6
2005	17	1237	4	309.2*	18.2
2006	16	270	2	135	8.4
2007	15	891	5	178.2	11.8
2008	14	869	5	173.8	12.4
2009	13	2282	7	326	25.1
2010	12	421	3	140.3	11.6
2011	11	932	7	133.1	12.1
2012	10	1327	10	132.7	13.3
2013	9	1199	7	171.3	19
2014	8	894	8	111.7	13.9
2015	7	443	4	110.7	15.8
2016	6	2699*	11*	245.4	40.9
2017	5	567	4	141.7	28.4
2018	4	881	6	146.8	36.7
2019	3	884	9	98.2	32.7
2020	2	326	2	163	81.5*
2021	1	0	0	0	0
*The Highest Number					

This information can be used to see in what year the top 100 cited publications were produced on the topic. From this study it was found that the highest year is 2016 (n=11 documents). In addition, from this study it was found that the highest year is 2016 (n=2,699 citations). The highest average citation per paper per year in 2020 is 81,5.

3.5 Literature review of digital learning to physics learning

Table 6. contains the results of the literature review by taking into account the quartiles, citations, and findings to provide recommendations regarding the selected paper.

Commented [P6]: Vague. Consider paraphrasing.

Table 6. Top 5 highest cited paper showing contribution of digital learning to physics learning

Author	SJR	Citation	Findings
Anderson, J. L., & Barnett, M. [26]	1,03 (Q1)	46	Digital learning with game simulations has a positive impact on the learning outcomes of junior high school students in physics learning.
Sengupta, P., Krinks, K. D., & Clark, D. B. [27]	4,06 (Q1)	22	The results of the study show that the combination of using digital learning fosters student physics learning motivation.
Melo, M. [28]	0,54 (Q2)	4	The use of digital learning 4C/ID model in physics content to students has a positive impact on learning outcomes.
Euler, E., Prytz, C., & Gregorcic, B. [29]	0,34 (Q3)	1	Digital learning using the Algodoo application gives students the opportunity to explore physics learning materials for free and able to attract students' attention in learning.
Sukarno & Widdah, M.E. [30]	0,49 (Q2)	1	Students' metacognitive and digital literacy skills increase in physics learning.

The ranking system of reputable journals based on the subject or category of the related journal field is also called quartiles [31]. From these results, it can be seen that the topic of digital learning has the highest citation 46, thus, research related to digital learning in physics will have a lot of potentials, and its novelty will be quite high. Digital learning tends to take advantage of interactive learning applications to increase student motivation and learning outcomes [32].

3.6 Advantage and disadvantage of digital learning to physics learning

Table 7. Discussion about digital learning

Discussion	Digital Learning
Meaning	Learning media that can be done digitally without having to wait for internet access to start.
Characteristics	• Some digital learning can be accessed without internet • Not tied to face-to-face or non-face-to-face learning • More towards the learning media
Advantage	Can be used in various places, can trigger students to think creatively and innovatively
Disadvantage	Can lead to dependence on digital tools so that it can cause laziness in students

From table 7., broadly speaking, it can be concluded that digital learning has advantages in flexibility and types of media that utilize sophisticated digital tools. While the disadvantages have an impact on students' lifestyles which can become dependent on digital learning media. The digital learning is a learning process that requires internet access, while digital learning does not always require internet access.

3.7 Analysis of the important role of interactive learning in physics based on digital learning research

Learning physics still tends to be difficult for most students to understand. Physics learning needs to be set more interactively for students. The use of interactive learning media can be integrated using a combination of video, graphics, text, and sound. Digital learning by applying interactive virtual reality can deepen students' understanding of physics material. In addition, through good quality worksheets in digital learning can be improved the students' critical thinking skills in learning physics. Practical activities can play an important role in engaging students with the world of science, especially when using digital tools. So, it can be concluded that interactive learning can improve student learning outcomes [33].

The majority of students in the 21st century is proficient in advanced technology and are adaptable. For example, the use of interactive modules is also very important to apply because, according to research [34], digital learning of physics with interactive modules shows compatibility and a positive impact. Since the last three years, the world has been affected by the pandemic, so academic units must also think about effective learning methods that can still improve student achievement. Therefore, interactive learning in physics is starting to be more widely applied. One of them is by using interactive multimedia, which is able to improve students' understanding of concepts [35]. Interactive learning plays an important role in deepening the concept of physics and making the learning atmosphere more interesting even through digital learning.

4. Conclusion

Research results analysis using bibliometric studies and literature reviews related to digital learning research get several conclusions. The conclusion is that the trend of digital learning topics is increased steadily, from 2014 to 2021. The most commonly used keywords are digital age, and digital literacy. The United States (US) has made the highest contribution over the last thirty years on digital learning. The author with the highest citation on digital learning is M. Papastergiou from Greece. The type of document that is often published in the article. The highest source titles digital learning is the paper *Computers and Education*. The highest average citation per paper per year is in 2020 where digital learning (n=81,5). The digital learning topics contribute to learning physics. From the explanation above, the future research related to digital learning in physics will have a lot of potentials, and its novelty will be quite high. The important role of interactive learning in physics is to improve student learning outcomes, train critical thinking skills, deepen understanding of concepts and make learning more interesting. The advantages in flexibility and types of media that utilize sophisticated digital tools. While the disadvantages have an impact on students' lifestyles which can become dependent on digital learning media and because it's using the internet network, which requires costs and a strong signal because not all areas have a strong network connection.

The implication of this research is to show the trend of publication of digital learning topics so that future researchers can show more benefits related to these topics. With this article, researchers can find out the strengths and weaknesses of digital learning topic and can find updates for future research. The limitation of the study is that some research results at Scopus are limited to full access. More intensively,

Commented [P8]: Vague. Consider paraphrasing.

Commented [P7]: The statement is contradictory.

Commented [P9]: The sentence is incomplete.

further research can be carried out by comparing other learning systems applied in physics learning.

5. Acknowledgement

The author's gratitude goes to the *Direktorat Jenderal Pendidikan Tinggi, Riset, dan Teknologi; Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, Indonesia* who has supported funding in *Penelitian Dasar Unggulan Perguruan Tinggi* - DRTPM 2022 [Contract Number: 29551/UN38.9/LK.04.00/2022].

References

[1] Dias Canedo E., Aymoré Martins V., Coelho Ribeiro V., dos Reis V.E., Carvalho Chaves L.A., Machado Gravina R., Alberto Moreira Dias F., Lopes de Mendonça F.L., Orozco A.L.S., Balaniuk R., de Sousa R.T Jr. (2021). Development and Evaluation of an Intelligence and Learning System in Jurisprudence Text Mining in the Field of Competition Defense. *Applied Sciences*, 11(23), 11365.https://doi.org/10.3390/app112311365

[2] Hsu, F. H., Lin, I. H., Yeh, H. C., & Chen, N. S. (2022). Effect of Socratic Reflection Prompts via video-based learning system on elementary school students' critical thinking skills. *Computers & Education*, *183*, 104497.https://doi.org/10.1016/j.compedu.2022.104497

[3] Hassan, T. (2022). A global update on covid-19 pandemic: Vaccines and new variants. *Pakistan Journal of Medicine & Dentistry*, 11(1), 89-93.https://doi.org/10.36283/PJMD11-1/015

[4] Donham, C., Barron, H. A., Alkhouri,J. S., Kumarath, M. C., Alejandro, W., Menke, E., & Kranzfelder, P. (2022). I will teach you here or there, I will try to teach you anywhere: perceived supports and barriers for emergency remote teaching during the COVID-19 pandemic.*International Journal of STEM Education*, 9(19), 1-25.https://doi.org/10.1186/s40594-022-00341-3

[5] Temelli, D. (2022). Reflexes of international organizations regarding education in the covid-19 pandemic process and comparing implementations in turkey. *Milli Egitim*, 51(233), 887-909.https://doi.org/10.37669/milliegitim.788444

[7] Olmes, G. L., Zimmermann, J. S. M., Stotz, L., Takacs, F. Z., Hamza, A., Radosa, M. P., Findeklee, S., Solomayer, E. F.,&Radosa, J. C. (2021). Students' attitudes toward digital learning during the covid-19 pandemic: a survey conducted following an online course in gynecology and obstetrics. *Archives of Gynecology and Obstetrics*, 304(4), 957-963.https://doi.org/10.1007/s00404-021-06131-6

[8] Guppy, N., Verpoorten, D., Boud, D., Lin, L., Tai. J., & Bartolic, S. (2022). The post-COVID-19 future of digital learning in higher education: Views from educators, students, and other professionals in six countries. *British Journal of Educational Technology*, 1(1), 1-22.https://doi.org/10.1111/bjet.13212

[9] Adde, D., Amponsah, S., & Gborti, B. J. (2022). Covid-19 pandemic and the shift to digital learning: experiences of students in a community college in ghana. *Community College Journal of Research and Practice*, 46(1), 101-112.https://doi.org/10.1080/10668926.2021.1972364

[10] Poluakan, C., & Katuuk, D. (2021). PIMCA: a new alternativesto physics learning model. *Journal of Physics: Conference Series*, 2165, 1-6.https://doi.org/10.1088/1742-6596/2165/1/012013

[11] Ivanec, T. P. (2022). The lack of academic social interactions and students' learning difficulties during covid-19 faculty lockdowns in Croatia: the mediating role of the perceived sense of life disruption caused by the pandemic and the adjustment to online studying. *Journal Social Science*, 11(42), 1-11.https://doi.org/10.3390/socsci11020042

[12] Vieyra, R., & Himmelsbach, J. (2022). Teachers' disciplinary boundedness in the implementation of integrated computational modeling in physics. *Journal of Science Education and Technology*, 31(2), 153-165.https://doi.org/10.1007/s10956-021-09938-9

[13] Dewantara, D., Sofianto, E. W. N., Misbah, &Munawaroh, D. (2021). Physics e-module: A review and bibliometric analysis. *Journal of Physics: Conference Series*, 2104, 1-7.https://doi.org/10.1088/1742-6596/2104/1/012008

[14] 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), 136-154.https://doi.org/10.3991/ijim.v15i08.20415

[15] Wang, J., Shen, L.,& Zhou, W. (2021). A bibliometric analysis of quantum computing literature: mapping and evidences from Scopus.*Technology Analysis and Strategic Management*, 33(11), 1347-1363.https://doi.org/10.1080/09537325.2021.1963429

[16] Kamaruzzaman, W. M., Nasir, N., Hamidi, N. A., Yusof, N., Shaifudin, M. S., Suhaimi, A. M. A. A. M., Badruddin, M. A., Adnan, A., Nik, W. M. N. W., & Ghazali, M. S. M. (2022). 25 years of progress on plants as corrosion inhibitors through a bibliometric analysis using the Scopus database (1995–2020). *Arabian Journal of Chemistry*, 15(4), 4-19.https://doi.org/10.1016/j.arabjc.2021.103655

[17] Kulkanjanapiban, P., & Silwattananusarn T. (2022). Comparative analysis of Dimensions and Scopus bibliographic data sources: An approach to university research productivity. *International Journal of Electrical and Computer Engineering*, 12(1) 706-720.https://doi.org/10.11591/ijece.v12i1.pp706-720

[18] Putri, C. R., Soleh, S. M., Saregar, A., Anugrah, A.,&Susilowati, N. E. (2021). Bibliometric analysis: Augmented reality-based physics laboratory with VOSviewer software. *Journal of Physics:*

Conference Series, 1796, 1-12.https://doi.org/10.1088/1742-6596/1796/1/012056

[19] Nishioka, C., & Farber, M. (2020). Trends of publications' citations and altmetrics based on open access types. Proceedings of the ACM/IEEE Joint Conference on Digital Libraries, 503-504.https://doi.org/10.1145/3383583.3398584

[20] Soehartono, A. M., Yu, L. G., & Khor, K. A. (2022). Essential signals in publication trends and collaboration patterns in global Research Integrity and Research Ethics (RIRE). *Scientometrics*, 1-11.https://doi.org/10.1007/s11192-022-04400-y

[21] Sousa, M. J., & Rocha, A. (2018). Special section on "emerging trends and challenges in digital learning". *Universal Access in the Information Society*, 17(4), 675-677.https://doi.org/10.1007/s10209-017-0572-6

[22] Zhao, L., Cao, C., Li, Y., & Li, Y. (2022). Determinants of the digital outcome divide in e-learning between rural and urban students: empirical evidence from the covid-19 pandemic based on capital theory. *Computers in Human Behavior*,130(1), 1-15.https://doi.org/10.1016/j.chb.2021.107177

[23] 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 and biomedical engineering*, 17(10), 144-159.https://doi.org/10.3991/ijoe.v17i10.25243

[24] Effendi, D. N., Irwandani, Anggraini, W., Jatmiko, A., Rahmayanti, H., Ichsan, I. Z., & Rahman, M. M. (2021). Bibliometric analysis of scientific literacy using VOS viewer: Analysis of science education. *Journal of Physics: Conference Series*, 1796, 1-10.https://doi.org/10.1088/1742-6596/1796/1/012096

[25] Pristianti, M. C. (2022). Top 100 cited research of confirmatory factor analysis (CFA) in education from 2012 to 2021. *International Journal of Current Educational Research*, 1(1), 68-83.https://doi.org/10.53621/ijocer.v1i1.140

[26] Anderson, J. L., & Barnett, M. (2013). Learning physics with digital game simulations in middle school science. *Journal of Science Education and Technology*, 22(6), 914-926.https://doi.org/10.1007/s10956-013-9438-8

[27] Sengupta, P.,Krinks, K. D., & Clark, D. B. (2015). Learning to deflect: conceptual change in physics during digital gameplay. *Journal of the Learning Sciences*, 24(4), 638-674.http://dx.doi.org/10.1080/10508406.2015.1082912

[28] Melo M. (2018). The 4C/ID-model in physics education: Instructional design of a digital learning environment to teach electrical circuits. *International Journal of Instruction*, 11(1), 103-122.https://doi.org/10.12973/iji.2018.1118a

[29] Euler, E., Prytz, C., & Gregorcic, B. (2020). Never far from shore: Productive patterns in physics students' use of the digital learning environment Algodoo. *Physics Education*, 55(4), 1-8.https://doi.org/10.1088/1361-6552/ab83e7

[30] Sukarno & Widdah, M.E. (2020). The effect of students' metacognition and digital literacy in virtual lectures during the covid-19 pandemic on achievement in the "methods and strategies on physics learning" course. *Jurnal Pendidikan IPA Indonesia*, 9(4), 477-488.https://doi.org/10.15294/jpii.v9i4.25332

[31] Arianto, M. A. & Basthomi, Y. (2021).The authors' research gap strategies in elt research article introductions: does Scopus journal quartile matter?. *Journal of Language and Linguistic Studies*, 17(4), 1743-1759.https://doi.org/10.52462/jlls.127

[32] Engerman, J. A., & Otto, R. F. (2021). The shift to digital: designing for learning from a culturally relevant interactive media perspective. *Educational Technology Research and Development*, 69(1), 301-305.https://doi.org/10.1007/s11423-020-09889-9

[33] Balaton, M., Cavadas, J., Carvalho, P. S., & Lima, J. J. G. (2021).Programming ozobots for teaching astronomy. *Physics Education*, 56(4), 1-8.https://doi.org/10.1088/1361-6552/abfb44

[34] Wongsuwan, W., Huntula, J.,&Liu, C. C. (2022).The interactive computer simulation and learning activity for facilitating students' conceptual understanding on the buoyant force through the CoSci learning platform. *Journal of Physics: Conference Series*, 2145, 1-6.https://doi.org/10.1088/1742-6596/2145/1/012075

[35] Susilowati, N. E., Samsudin, A., & Muslim. (2021).What do physics teachers need? A need analysis of interactive multimedia to train creative thinking in static fluid. *Journal of Physics: Conference Series*, 2098, 1-6.https://doi.org/10.1088/1742-6596/2098/1/012029

Digital Learning Research in the Last 30 Years: Important Role of Interactive Learning in Physics

Binar Kurnia Prahani[1], Mila Candra Pristianti[1], Budi Jatmiko[1], Tan Amelia[2], Firmanul Catur Wibowo[3]

[1]*Universitas Negeri Surabaya, Surabaya, Indonesia*
[2]*Universitas Dinamika,Surabaya, Indonesia*
[3] *Universitas Negeri Jakarta,Jakarta, Indonesia*
binarprahani@unesa.ac.id

***Abstract* – The aim is to analyze top 100 highest citations of digital learning research topics and the important role of interactive learning in physics in 1992-2021. This study uses bibliometric analysis and literature review. The trend of digital learning topics is increasing steadily, from 2014 to 2021. Digital learning shows an excellent contribution to physics learning. The important role of interactive learning in physics is to improve student learning outcomes, deepen understanding and make learning more interesting. More intensively, further research can be carried out by comparing other learning systems applied in physics learning.**

***Keywords* – bibliometric, digital learning, education, physics learning**

1. Introduction

Various kinds of learning systems have been applied according to surrounding conditions, the example is digital learning. The development of learning systems must pay attention to the ease of adaptation and transformation [1], [2]. Learning development can be done by combining organizational learning theory and general systems theory.

There are many impacts of the covid-19 pandemic, one of which is in the world of education. One of the updates from the covid-19 case on October 10, 2021, all countries have reported 219 million positive cases of covid-19 with 4.55 million deaths [3]. With the danger that threatens, many countries are trying to make learning sustainable [4]. Efforts are made to organize healthy learning during the covid-19 pandemic crisis [5]. The covid-19 outbreak has led to the closure of schools and colleges, so educational institutions are designed to be more flexible, namely the learning process can be carried out even though it is not face-to-face, reducing learning hours and utilizing digital platforms. Research conducted by Leonhard [6], Neil [7], and David [8] concluded that during the covid-19 pandemic, student responses showed good acceptance of digital learning. Students accepted and adapted easily to digital technology during the covid-19 pandemic.

Physics learning is closely related to natural phenomena and experimental activities. The flexibility of physics learning can be done using digital technology or without it [9]. By learning physics through digital learning students are challenged to be more independent, must easily adapt and be willing to learn. However, there are shortcomings in the implementation of digital learning, namely some places have limited access to digital media and potential dependence on digital technology [10]. Mentoring and supervision by physics teachers will determine the success of digital learning [11].

DOI: 10.18421/TEMxx-xx
https://doi.org/10.18421/TEMxx-xx

Corresponding author: Binar Kurnia Prahani, Universitas Negeri Surabaya, Indonesia

Email: binarprahani@unesa.ac.id

Received: -----.
Accepted: -----.
Published: -----.

From the existing studies, there is still no discussion that shows the contribution of digital learning in physics learning and the important role of interactive learning in physics. Some studies tend to discuss digital learning, but to show the right data regarding the analysis, bibliometric studies and literature reviews are needed. Bibliometric analysis is a method to provide knowledge regarding the growth and flow of literature in a particular publication field [12]. This bibliometric study uses empirical data to track existing publications [13]. This study can analyze the distribution of manuscripts sorted by country, source, year and more [14].

This research was carried out with an explanation of the importance of digital learning as well as the existing shortcomings. The aim is to analyze top 100 highest citations of digital learning research topics, and the important role of interactive learning in physics from 1992 to 2021. For analysis are used bibliometrics and also literature review. The objective research included:

1. Analysis of the trend of digital learning publications from the last thirty years.
2. Identifying the most widely used keywords, the country and author that contribute the most to the publication of digital learning in the last thirty years.
3. Identifying document types and source titles for digital learning from the last thirty years.
4. Identifying the year wise distribution of the top 100 cited digital learning publications from the last thirty years.
5. Identifying the contribution of digital learning in physics learning over the last thirty years.
6. Identifying the advantages and disadvantages of digital learning.
7. Analysis of the important role of interactive learning in physics.

2. Methods

This study uses bibliometric analysis and literature review. The data used in this study were taken from Scopus. Scopus is well-known for its largest database of publications in various fields including academic fields such as natural sciences, computing and others [15], [16]. Data from Scopus can be adjusted according to the needs of the year, title, country, keywords, and so on [17]. In addition, this study uses a literature review from previous studies as a reinforcement of research data.

Research data was taken on April 1, 2022. The data in Scopus is selected based on the keywords you want to search for. In this study, the keyword selection stage was carried out twice, the first regarding digital learning. Furthermore, the second keywords are connected with physics learning to find the contribution of digital learning, more details can be seen in Figure 1. The data was obtained in the form of .csv which was then analyzed using Microsoft excel and .ris which was analyzed using VOSViewer [18].

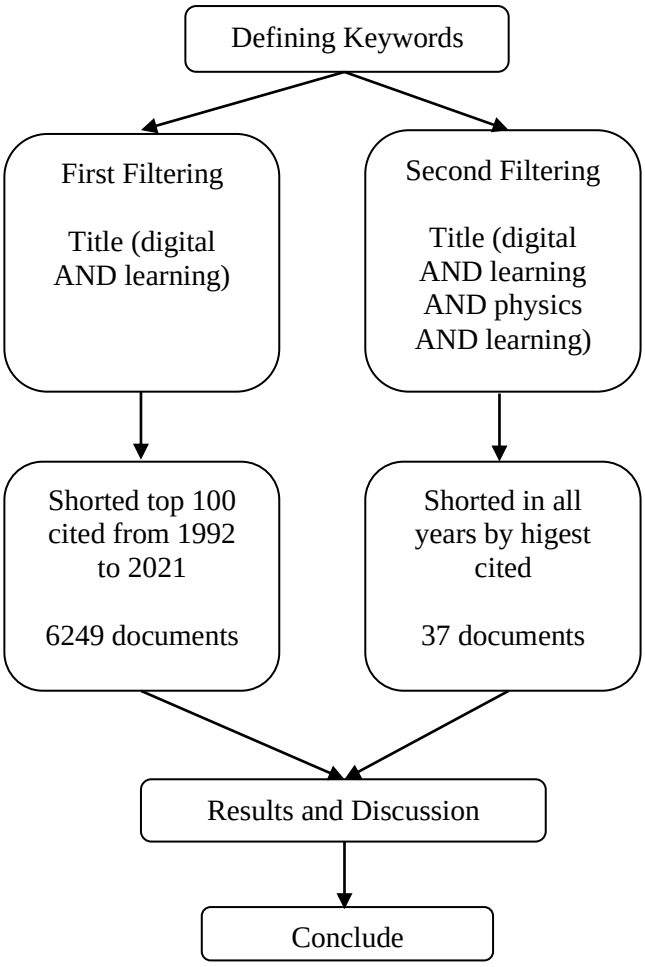

Figure 1. Flowchart for the keyword filtering

3. Results and discussion

3.1 Publication trend in the last 30 years

From Figure 2., we can see the trend of publications related to digital learning. The trend of publication is an important aspect to pay attention to and follow up [19]. Considering that publications must be in accordance with current conditions, which mean the development of a topic is determined from the trend of publications each year [20].

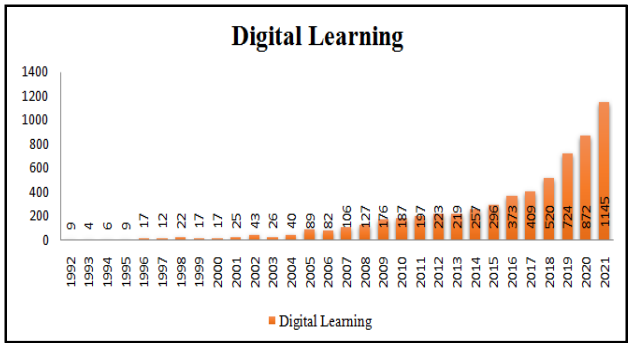

Figure 2. Digital learning publication trends

The highest digital learning publication was in 2021 with 1145 documents and the lowest in 1993 with 4 documents. Digital learning publications began to increase steadily, from 2014 to 2021. The highest increase occurred in 2021 with as many as 273 documents from 2020. The researchers tend to be interested in raising the topic of digital learning [21]. This is in line with the fact that the majority of education in the world has used digital learning due to the emergence of the Covid-19 pandemic [22]. So that research related to digital learning has high potential for future research.

3.2 Visualization of the most used keywords, top countries and top authors who contributed the most

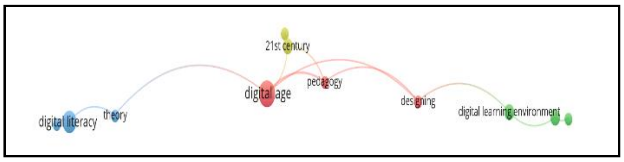

Figure 3. The keywords visualization of digital learning

Figure 3. shows the keyword visualization using VOSViewer. Keywords can describe the subject matter in a publication [23]. For digital learning topics, the most commonly used keyword is "digital age" which has 8 occurrences and "digital literacy" has 6 occurrences.

Table 1. Comparison of the top 10 countries with the most publications in the last thirty years

Top 10 countries	Publications
United States	1,359
United Kingdom	460
China	422
Germany	347
Australia	319
Taiwan	306
Spain	281
Indonesia	221
Canada	208
India	187

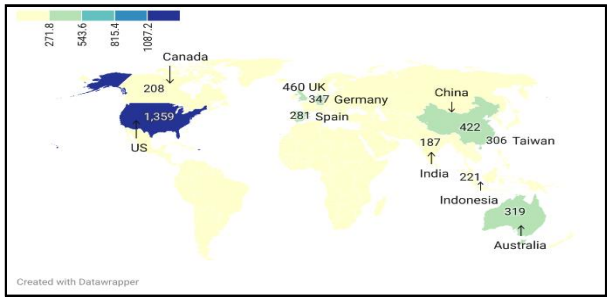

Figure 4. Top 10 Countries with publications about digital learning

From Table 1. and Figure 4., it can be concluded that the United States produced the highest number of papers over the last thirty years on the topic of digital learning. There are five countries that consistently occupy the top 10 on all publication topics related to digital learning including the United States, China, United Kingdom, Australia and Spain. To identify the author who has the most publications on each topic of digital learning, we were using VOS viewer and Microsoft Excel analysis. The results of the Microsoft Excel analysis are shown in Table 2.

Table 2. The top 10 author with the highest citations in the last thirty years

Author	Total Citations	Country
M. Papastergiou	1,880	Greece
K. Kiili	1,978	Finland
C.M. Greenhow	2,509	United States
A.R. Janowczyk	1,269	United States
D.B. Clark	3,069	Canada
A. Madabhushi	14,845*	United States
B. Gros	660	Spain
S. Erhel	429	France
A. Sadik	367	Egypt
B.Q. Huynh	590	United States

Table 2. shows the top 10 authors from the highest citations for the topic of digital learning, M. Papastergiou from Greece. Meanwhile, the highest total citation was owned by A. Madabhushi from the United States. To find out which writers on digital learning topics produce the most digital learning papers and who are most connected to other authors, we can use a software called VOSViewer. With VOSViewer we can identify the classification of top authors [24]. The grouping and connection of each author is indicated by the presence of clusters [25]. The first results of the digital learning topic are divided into 3 clusters, namely red (n=5), green (4), blue (n=2). H. Beetham is the main author because he has 3 documents with 2 total links strength which is more than any other author.

3.3 The document types and source titles of top 100 highest cited publications in the last 30 years

Table 3. The document types of top 100 highest cited digital learning publication in the last 30 years

Document Type	Freq-uency	Cited	Mean	Med-ian	SD
Article	81*	14206*	175.3	125	160.8*
Conference paper	7	808	115.4	95	47.2
Review	4	810	202.5*	209.5*	96.6
Note	0	0	0	0	-
Book	7	1011	144.4	129	63.1
Editorial	1	376	376	376	-

Table 3. shows digital learning topics, most of the publications are in the form of articles (n=81). Digital learning has been totally cited 14,206. The standard deviation is quite high, namely digital learning (n=160.8).

Table 4. The source titles of top 100 highest cited publication in the last 30 years

Source Title	TD	TC
Computers and Education	13	2983
Educational Technology and Society	4	415
Journal of Computer Assisted Learning	3	565
Journal of Research on Technology in Education	3	530
Language and Learning in the Digital Age	3	468
Geoderma	3	386
ReCALL	3	325
Internet and Higher Education	2	1008
Rethinking Pedagogy for a Digital Age: Designing and Delivering E-Learning	2	343
Learning, Media and Technology	2	264
TD = Total Documents TC = Total Citations		

Table 4. shows that the source titles of digital learning are varied and we can see that the source title which produces the most digital learning topics, namely Computers and Education (n=13 documents). The highest total citation is 2,983 namely source title is Computers and Education.

3.4 The year wise distribution of top 100 highest cited publications in the last 30 years

Table 5. contains information on the distribution of the top 100 cited publications on the topics of digital learning. The range of data used is from 1992 to 2021.

Table 5. The year wise distribution of top 100 highest cited publications in the last 30 years

Year	Citable Year	Digital Learning			
		TC	TD	ACPP	ACPPY
1992	30	0	0	0	0
1993	29	0	0	0	0
1994	28	0	0	0	0
1995	27	215	2	107.5	3.9
1996	26	0	0	0	0
1997	25	0	0	0	0
1998	24	0	0	0	0
1999	23	0	0	0	0
2000	22	0	0	0	0
2001	21	420	2	210	10
2002	20	0	0	0	0
2003	19	0	0	0	0
2004	18	454	2	227	12.6
2005	17	1237	4	309.2*	18.2
2006	16	270	2	135	8.4
2007	15	891	5	178.2	11.8
2008	14	869	5	173.8	12.4
2009	13	2282	7	326	25.1
2010	12	421	3	140.3	11.6
2011	11	932	7	133.1	12.1
2012	10	1327	10	132.7	13.3
2013	9	1199	7	171.3	19
2014	8	894	8	111.7	13.9
2015	7	443	4	110.7	15.8
2016	6	2699*	11*	245.4	40.9
2017	5	567	4	141.7	28.4
2018	4	881	6	146.8	36.7
2019	3	884	9	98.2	32.7
2020	2	326	2	163	81.5*
2021	1	0	0	0	0
*The Highest Number					

This information can be used to see in what year the top 100 cited publications were produced on the topic. From this study it was found that the highest year is 2016 (n=11 documents). In addition, from this study it was found that the highest year is 2016 (n=2,699 citations). The highest average citation per paper per year in 2020 is 81,5.

3.5 Literature review of digital learning to physics learning

Table 6. contains the results of the literature review by taking into account the quartiles, citations, and findings to provide recommendations regarding the selected paper.

Table 6. Top 5 highest cited paper showing contribution of digital learning to physics learning

Author	SJR	Citation	Findings
Anderson, J. L., & Barnett, M. [26]	1,03 (Q1)	46	Digital learning with game simulations has a positive impact on the learning outcomes of junior high school students in physics learning.
Sengupta, P., Krinks, K. D., & Clark, D. B. [27]	4,06 (Q1)	22	The results of the study show that the combination of using digital learning fosters student physics learning motivation.
Melo, M. [28]	0,54 (Q2)	4	The use of digital learning 4C/ID model in physics content to students has a positive impact on learning outcomes.
Euler, E., Prytz, C., & Gregorcic, B. [29]	0,34 (Q3)	1	Digital learning using the Algodoo application gives students the opportunity to explore physics learning materials for free and able to attract students' attention in learning.
Sukarno & Widdah, M.E. [30]	0,49 (Q2)	1	Students' metacognitive and digital literacy skills increase in physics learning.

The ranking system of reputable journals based on the subject or category of the related journal field is also called quartiles [31]. From these results, it can be seen that the topic of digital learning has the highest citation 46, thus, research related to digital learning in physics will have a lot of potentials, and its novelty will be quite high. Digital learning tends to take advantage of interactive learning applications to increase student motivation and learning outcomes [32].

3.6 Advantage and disadvantage of digital learning to physics learning

Table 7. Discussion about digital learning

Discussion	Digital Learning
Meaning	Learning media that can be done digitally without having to wait for internet access to start.
Characteristics	• Some digital learning can be accessed without internet • Not tied to face-to-face or non-face-to-face learning • More towards the learning media
Advantage	Can be used in various places, can trigger students to think creatively and innovatively
Disadvantage	Can lead to dependence on digital tools so that it can cause laziness in students

From table 7., broadly speaking, it can be concluded that digital learning has advantages in flexibility and types of media that utilize sophisticated digital tools. While the disadvantages have an impact on students' lifestyles which can become dependent on digital learning media.

3.7 Analysis of the important role of interactive learning in physics based on digital learning research

Learning physics still tends to be difficult for most students to understand. Physics learning needs to be set more interactively for students. The use of interactive learning media can be integrated using a combination of video, graphics, text, and sound. Digital learning by applying interactive virtual reality can deepen students' understanding of physics material. In addition, through good quality worksheets in digital learning can be improved the students' critical thinking skills in learning physics. Practical activities can play an important role in engaging students with the world of science, especially when using digital tools. So, it can be concluded that interactive learning can improve student learning outcomes [33].

The majority of students in the 21st century is proficient in advanced technology and are adaptable. For example, the use of interactive modules is also very important to apply because, according to research [34], digital learning of physics with interactive modules shows compatibility and a positive impact. Since the last three years, the world has been affected by the pandemic, so academic units must also think about effective learning methods that can still improve student achievement. Therefore, interactive learning in physics is starting to be more widely applied. One of them is by using interactive multimedia, which is able to improve students' understanding of concepts [35]. Interactive learning plays an important role in deepening the concept of physics and making the learning atmosphere more interesting even through digital learning.

4. Conclusion

Research results analysis using bibliometric studies and literature reviews related to digital learning research get several conclusions. The conclusion is that the trend of digital learning topics is increased steadily, from 2014 to 2021. The most commonly used keywords are digital age, and digital literacy. The United States (US) has made the highest contribution over the last thirty years on digital learning. The author with the highest citation on digital learning is M. Papastergiou from Greece. The type of document that is often published by the author is in the form of articles. The highest source titles digital learning is the paper *Computers and Education*. The highest average citation per paper per year is in 2020 where digital learning (n=81,5). The digital learning topics contribute to learning physics. From the explanation above, the future research related to digital learning in physics will have a lot of potentials, and its novelty will be quite high. The important role of interactive learning in physics is to improve student learning outcomes, train critical thinking skills, deepen understanding of concepts and make learning more interesting. The advantages of digital learning is in flexibility such as the learning process can be carried out even though it is not face-to-face, reducing learning hours and types of media that utilize sophisticated digital tools. While the disadvantages have an impact on students' lifestyles which can become dependent on digital learning media and because it’s using the internet network, which requires costs and a strong signal because not all areas have a strong network connection.

The implication of this research is to show the trend of publication of digital learning topics so that future researchers can show more benefits related to these topics. With this article, researchers can find out the strengths and weaknesses of digital learning topic and can find updates for future research. The limitation of the study is that some research results at Scopus are limited to full access. More intensively, further research can be carried out by comparing other learning systems applied in physics learning.

5. Acknowledgement

The author's gratitude goes to the *Direktorat Jenderal Pendidikan Tinggi, Riset, dan Teknologi; Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, Indonesia* who has supported funding in *Penelitian Dasar Unggulan Perguruan Tinggi* - DRTPM 2022 [Contract Number: 29551/UN38.9/LK.04.00/2022].

References

[1] Dias Canedo E., Aymoré Martins V., Coelho Ribeiro V., dos Reis V.E., Carvalho Chaves L.A., Machado Gravina R., Alberto Moreira Dias F., Lopes de Mendonça F.L., Orozco A.L.S., Balaniuk R., de Sousa R.T Jr. (2021). Development and Evaluation of an Intelligence and Learning System in Jurisprudence Text Mining in the Field of Competition Defense. *Applied Sciences*, 11(23), 11365. https://doi.org/10.3390/app112311365

[2] Hsu, F. H., Lin, I. H., Yeh, H. C., & Chen, N. S. (2022). Effect of Socratic Reflection Prompts via video-based learning system on elementary school students' critical thinking skills. *Computers & Education*, *183*, 104497. https://doi.org/10.1016/j.compedu.2022.104497

[3] Hassan, T. (2022). A global update on covid-19 pandemic: Vaccines and new variants. *Pakistan Journal of Medicine & Dentistry*, 11(1), 89-93. https://doi.org/10.36283/PJMD11-1/015

[4] Donham, C., Barron, H. A., Alkhouri,J. S., Kumarath, M. C., Alejandro, W., Menke, E., & Kranzfelder, P. (2022). I will teach you here or there, I will try to teach you anywhere: perceived supports and barriers for emergency remote teaching during the COVID-19 pandemic. *International Journal of STEM Education*, 9(19), 1-25. https://doi.org/10.1186/s40594-022-00341-3

[5] Temelli, D. (2022). Reflexes of international organizations regarding education in the covid-19 pandemic process and comparing implementations in turkey. *Milli Egitim*, 51(233), 887-909. https://doi.org/10.37669/milliegitim.788444

[7] Olmes, G. L., Zimmermann, J. S. M., Stotz, L., Takacs, F. Z., Hamza, A., Radosa, M. P., Findeklee, S., Solomayer, E. F.,&Radosa, J. C. (2021). Students' attitudes toward digital learning during the covid-19 pandemic: a survey conducted following an online course in gynecology and obstetrics. *Archives of Gynecology and Obstetrics*, 304(4), 957-963. https://doi.org/10.1007/s00404-021-06131-6

[8] Guppy, N., Verpoorten, D., Boud, D., Lin, L., Tai. J., & Bartolic, S. (2022). The post-COVID-19 future of digital learning in higher education: Views from educators, students, and other professionals in six countries. *British Journal of Educational Technology*, 1(1), 1-22. https://doi.org/10.1111/bjet.13212

[9] Adde, D., Amponsah, S., & Gborti, B. J. (2022). Covid-19 pandemic and the shift to digital learning: experiences of students in a community college in ghana. *Community College Journal of Research and Practice*, 46(1), 101-112. https://doi.org/10.1080/10668926.2021.1972364

[10] Poluakan, C., & Katuuk, D. (2021). PIMCA: a new alternativesto physics learning model. *Journal of Physics: Conference Series*, 2165, 1-6.https://doi.org/10.1088/1742-6596/2165/1/012013

[11] Ivanec, T. P. (2022). The lack of academic social interactions and students' learning difficulties during covid-19 faculty lockdowns in Croatia: the mediating role of the perceived sense of life disruption caused by the pandemic and the adjustment to online studying. *Journal Social Science*, 11(42), 1-11. https://doi.org/10.3390/socsci11020042

[12] Vieyra, R., & Himmelsbach, J. (2022). Teachers' disciplinary boundedness in the implementation of integrated computational modeling in physics. *Journal of Science Education and Technology*, 31(2), 153-165. https://doi.org/10.1007/s10956-021-09938-9

[13] Dewantara, D., Sofianto, E. W. N., Misbah, & Munawaroh, D. (2021). Physics e-module: A review and bibliometric analysis. *Journal of Physics: Conference Series*, 2104, 1-7. https://doi.org/10.1088/1742-6596/2104/1/012008

[14] 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), 136-154. https://doi.org/10.3991/ijim.v15i08.20415

[15] Wang, J., Shen, L.,& Zhou, W. (2021). A bibliometric analysis of quantum computing literature: mapping and evidences from Scopus. *Technology Analysis and Strategic Management*, 33(11), 1347-1363. https://doi.org/10.1080/09537325.2021.1963429

[16] Kamaruzzaman, W. M., Nasir, N., Hamidi, N. A., Yusof, N., Shaifudin, M. S., Suhaimi, A. M. A. A. M., Badruddin, M. A., Adnan, A., Nik, W. M. N. W., & Ghazali, M. S. M. (2022). 25 years of progress on plants as corrosion inhibitors through a bibliometric analysis using the Scopus database (1995–2020). *Arabian Journal of Chemistry*, 15(4), 4-19. https://doi.org/10.1016/j.arabjc.2021.103655

[17] Kulkanjanapiban, P., & Silwattananusarn T. (2022). Comparative analysis of Dimensions and Scopus bibliographic data sources: An approach to university research productivity. *International Journal of Electrical and Computer Engineering*, 12(1) 706-720. https://doi.org/10.11591/ijece.v12i1.pp706-720

[18] Putri, C. R., Soleh, S. M., Saregar, A., Anugrah, A., &Susilowati, N. E. (2021). Bibliometric analysis: Augmented reality-based physics laboratory with VOSviewer software. *Journal of Physics: Conference Series*, 1796, 1-12. https://doi.org/10.1088/1742-6596/1796/1/012056

[19] Nishioka, C., & Farber, M. (2020). Trends of publications' citations and altmetrics based on open access types. Proceedings of the ACM/IEEE Joint Conference on Digital Libraries, 503-504. https://doi.org/10.1145/3383583.3398584

[20] Soehartono, A. M., Yu, L. G., & Khor, K. A. (2022). Essential signals in publication trends and collaboration patterns in global Research Integrity and Research Ethics (RIRE). *Scientometrics*, 1-11. https://doi.org/10.1007/s11192-022-04400-y

[21] Sousa, M. J., & Rocha, A. (2018). Special section on "emerging trends and challenges in digital learning". *Universal Access in the Information Society*, 17(4), 675-677. https://doi.org/10.1007/s10209-017-0572-6

[22] Zhao, L., Cao, C., Li, Y., & Li, Y. (2022). Determinants of the digital outcome divide in e-learning between rural and urban students: empirical evidence from the covid-19 pandemic based on capital theory. *Computers in Human Behavior*,130(1), 1-15. https://doi.org/10.1016/j.chb.2021.107177

[23] 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 and biomedical engineering*, 17(10), 144-159. https://doi.org/10.3991/ijoe.v17i10.25243

[24] Effendi, D. N., Irwandani, Anggraini, W., Jatmiko, A., Rahmayanti, H., Ichsan, I. Z., & Rahman, M. M. (2021). Bibliometric analysis of scientific literacy using VOS viewer: Analysis of science education. *Journal of Physics: Conference Series*, 1796, 1-10. https://doi.org/10.1088/1742-6596/1796/1/012096

[25] Pristianti, M. C. (2022). Top 100 cited research of confirmatory factor analysis (CFA) in education from 2012 to 2021. *International Journal of Current Educational Research*, 1(1), 68-83. https://doi.org/10.53621/ijocer.v1i1.140

[26] Anderson, J. L., & Barnett, M. (2013). Learning physics with digital game simulations in middle school science. *Journal of Science Education and Technology*, 22(6), 914-926. https://doi.org/10.1007/s10956-013-9438-8

[27] Sengupta, P., Krinks, K. D., & Clark, D. B. (2015). Learning to deflect: conceptual change in physics during digital gameplay. *Journal of the Learning Sciences*, 24(4), 638-674. http://dx.doi.org/10.1080/10508406.2015.1082912

[28] Melo M. (2018). The 4C/ID-model in physics education: Instructional design of a digital learning environment to teach electrical circuits. *International Journal of Instruction*, 11(1), 103-122. https://doi.org/10.12973/iji.2018.1118a

[29] Euler, E., Prytz, C., & Gregorcic, B. (2020). Never far from shore: Productive patterns in physics students' use of the digital learning environment Algodoo. *Physics Education*, 55(4), 1-8. https://doi.org/10.1088/1361-6552/ab83e7

[30] Sukarno & Widdah, M.E. (2020). The effect of students' metacognition and digital literacy in virtual lectures during the covid-19 pandemic on achievement in the "methods and strategies on physics learning" course. *Jurnal Pendidikan IPA Indonesia*, 9(4), 477-488. https://doi.org/10.15294/jpii.v9i4.25332

[31] Arianto, M. A. & Basthomi, Y. (2021). The authors' research gap strategies in elt research article introductions: does Scopus journal quartile matter?. *Journal of Language and Linguistic Studies*, 17(4), 1743-1759. https://doi.org/10.52462/jlls.127

[32] Engerman, J. A., & Otto, R. F. (2021). The shift to digital: designing for learning from a culturally relevant interactive media perspective. *Educational Technology Research and Development*, 69(1), 301-305. https://doi.org/10.1007/s11423-020-09889-9

[33] Balaton, M., Cavadas, J., Carvalho, P. S., & Lima, J. J. G. (2021). Programming ozobots for teaching astronomy. *Physics Education*, 56(4), 1-8. https://doi.org/10.1088/1361-6552/abfb44

[34] Wongsuwan, W., Huntula, J.,&Liu, C. C. (2022).The interactive computer simulation and learning activity for facilitating students' conceptual understanding on the buoyant force through the CoSci learning platform. *Journal of Physics: Conference Series*, 2145, 1-6. https://doi.org/10.1088/1742-6596/2145/1/012075

[35] Susilowati, N. E., Samsudin, A., & Muslim. (2021). What do physics teachers need? A need analysis of interactive multimedia to train creative thinking in static fluid. *Journal of Physics: Conference Series*, 2098, 1-6. https://doi.org/10.1088/1742-6596/2098/1/012029

Digital Learning Research in the Last 30 Years: Important Role of Interactive Learning in Physics

Binar Kurnia Prahani [1], Mila Candra Pristianti [1], Budi Jatmiko [1], Tan Amelia [2], Firmanul Catur Wibowo [3]

[1] *Universitas Negeri Surabaya, Surabaya, Indonesia*
[2] *Universitas Dinamika,Surabaya, Indonesia*
[3] *Universitas Negeri Jakarta,Jakarta, Indonesia*

Abstract **– The aim is to analyze top 100 highest citations of digital learning research topics and the important role of interactive learning in physics in 1992-2021. This study uses bibliometric analysis and literature review. The trend of digital learning topics is increasing steadily, from 2014 to 2021. Digital learning shows an excellent contribution to physics learning. The important role of interactive learning in physics is to improve student learning outcomes, deepen understanding and make learning more interesting. More intensively, further research can be carried out by comparing other learning systems applied in physics learning.**

Keywords **– bibliometric, digital learning, education, physics learning.**

1. Introduction

Various kinds of learning systems have been applied according to surrounding conditions, the example is digital learning.

DOI: 10.18421/TEM113-46
https://doi.org/10.18421/TEM113-46

Corresponding author: Binar Kurnia Prahani,
Universitas Negeri Surabaya, Indonesia.
Email: binarprahani@unesa.ac.id

Received: 10 May 2022.
Revised: 06 August 2022.
Accepted: 12 August 2022.
Published: 29 August 2022.

The development of learning systems must pay attention to the ease of adaptation and transformation [1], [2]. Learning development can be done by combining organizational learning theory and general systems theory.

There are many impacts of the covid-19 pandemic, one of which is in the world of education. One of the updates from the covid-19 case on October 10, 2021, all countries have reported 219 million positive cases of covid-19 with 4.55 million deaths [3]. With the danger that threatens, many countries are trying to make learning sustainable [4]. Efforts are made to organize healthy learning during the covid-19 pandemic crisis [5]. The covid-19 outbreak has led to the closure of schools and colleges, so educational institutions are designed to be more flexible, namely the learning process can be carried out even though it is not face-to-face, reducing learning hours and utilizing digital platforms. Research conducted by Schirmel [6], Neil [7], and David [8] concluded that during the covid-19 pandemic, student responses showed good acceptance of digital learning. Students accepted and adapted easily to digital technology during the covid-19 pandemic.

Physics learning is closely related to natural phenomena and experimental activities. The flexibility of physics learning can be done using digital technology or without it [9]. By learning physics through digital learning students are challenged to be more independent, must easily adapt and be willing to learn. However, there are shortcomings in the implementation of digital learning, namely some places have limited access to digital media and potential dependence on digital technology [10]. Mentoring and supervision by physics teachers will determine the success of digital learning [11].

From the existing studies, there is still no discussion that shows the contribution of digital learning in physics learning and the important role of

interactive learning in physics. Some studies tend to discuss digital learning, but to show the right data regarding the analysis, bibliometric studies and literature reviews are needed. Bibliometric analysis is a method to provide knowledge regarding the growth and flow of literature in a particular publication field [12]. This bibliometric study uses empirical data to track existing publications [13]. This study can analyze the distribution of manuscripts sorted by country, source, year and more [14].

This research was carried out with an explanation of the importance of digital learning as well as the existing shortcomings. The aim is to analyze top 100 highest citations of digital learning research topics, and the important role of interactive learning in physics from 1992 to 2021. For analysis are used bibliometrics and also literature review. The objective research included:

1. Analysis of the trend of digital learning publications from the last thirty years.
2. Identifying the most widely used keywords, the country and author that contribute the most to the publication of digital learning in the last thirty years.
3. Identifying document types and source titles for digital learning from the last thirty years.
4. Identifying the year wise distribution of the top 100 cited digital learning publications from the last thirty years.
5. Identifying the contribution of digital learning in physics learning over the last thirty years.
6. Identifying the advantages and disadvantages of digital learning.
7. Analysis of the important role of interactive learning in physics.

2. Methods

This study uses bibliometric analysis and literature review. The data used in this study were taken from Scopus. Scopus is well-known for its largest database of publications in various fields including academic fields such as natural sciences, computing and others [15], [16]. Data from Scopus can be adjusted according to the needs of the year, title, country, keywords, and so on [17]. In addition, this study uses a literature review from previous studies as a reinforcement of research data.

Research data was taken on April 1, 2022. The data in Scopus is selected based on the keywords you want to search for. In this study, the keyword selection stage was carried out twice, the first regarding digital learning. Furthermore, the second keywords are connected with physics learning to find the contribution of digital learning, more details can be seen in Figure 1. The data was obtained in the form of .csv which was then analyzed using Microsoft excel and .ris which was analyzed using VOSViewer [18].

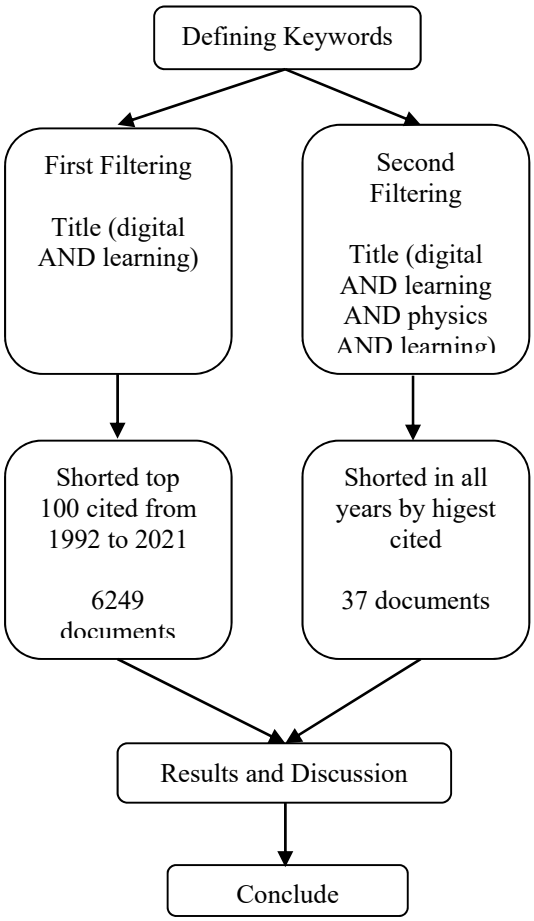

Figure 1. Flowchart for the keyword filtering

3. Results and Discussion

3.1. Publication Trend in the Last 30 Years

From Figure 2., we can see the trend of publications related to digital learning. The trend of publication is an important aspect to pay attention to and follow up [19]. Considering that publications must be in accordance with current conditions, which mean the development of a topic is determined from the trend of publications each year [20].

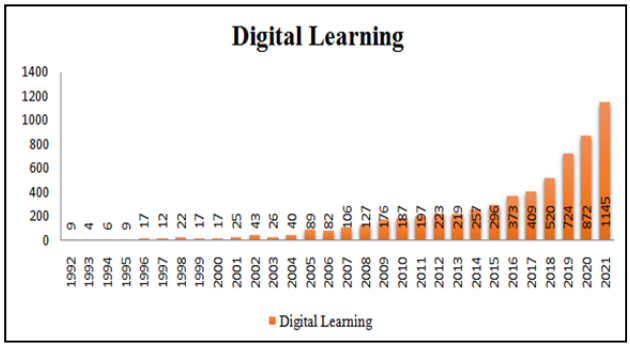

Figure 2. Digital learning publication trends

The highest digital learning publication was in 2021 with 1145 documents and the lowest in 1993 with 4 documents. Digital learning publications began to increase steadily, from 2014 to 2021. The highest increase occurred in 2021 with as many as 273 documents from 2020. The researchers tend to be interested in raising the topic of digital learning [21]. This is in line with the fact that the majority of education in the world has used digital learning due to the emergence of the Covid-19 pandemic [22]. So that research related to digital learning has high potential for future research.

3.2. Visualization of the Most Used Keywords, Top Countries and Top Authors Who Contributed the Most

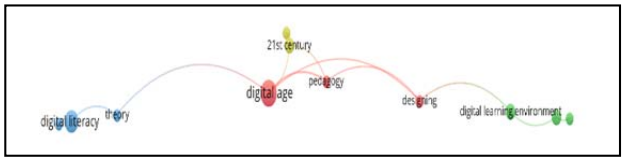

Figure 3. The keywords visualization of digital learning

Figure 3. shows the keyword visualization using VOSViewer. Keywords can describe the subject matter in a publication [23]. For digital learning topics, the most commonly used keyword is "digital age" which has 8 occurrences and "digital literacy" has 6 occurrences.

Table 1. Comparison of the top 10 countries with the most publications in the last thirty years

Top 10 countries	Publications
United States	1,359
United Kingdom	460
China	422
Germany	347
Australia	319
Taiwan	306
Spain	281
Indonesia	221
Canada	208
India	187

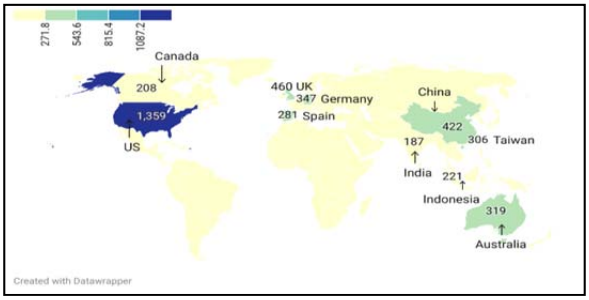

Figure 4. Top 10 Countries with publications about digital learning

From Table 1. and Figure 4., it can be concluded that the United States produced the highest number of papers over the last thirty years on the topic of digital learning. There are five countries that consistently occupy the top 10 on all publication topics related to digital learning including the United States, China, United Kingdom, Australia and Spain. To identify the author who has the most publications on each topic of digital learning, we were using VOS viewer and Microsoft Excel analysis. The results of the Microsoft Excel analysis are shown in Table 2.

Table 2. The top 10 author with the highest citations in the last thirty years

Author	Total Citations	Country
M. Papastergiou	1,880	Greece
K. Kiili	1,978	Finland
C.M. Greenhow	2,509	United States
A.R. Janowczyk	1,269	United States
D.B. Clark	3,069	Canada
A. Madabhushi	14,845*	United States
B. Gros	660	Spain
S. Erhel	429	France
A. Sadik	367	Egypt
B.Q. Huynh	590	United States

Table 2. shows the top 10 authors from the highest citations for the topic of digital learning, M. Papastergiou from Greece. Meanwhile, the highest total citation was owned by A. Madabhushi from the United States. To find out which writers on digital learning topics produce the most digital learning papers and who are most connected to other authors, we can use a software called VOSViewer. With VOSViewer we can identify the classification of top authors [24]. The grouping and connection of each author is indicated by the presence of clusters [25]. The first results of the digital learning topic are divided into 3 clusters, namely red (n=5), green (4), blue (n=2). H. Beetham is the main author because he has 3 documents with 2 total links strength which is more than any other author.

3.3. The Document Types and Source Titles of Top 100 Highest Cited Publications in the Last 30 Years

Table 3. The document types of top 100 highest cited digital learning publication in the last 30 years

Document Type	Freq-uency	Cited	Mean	Med-ian	SD
Article	81*	14206*	175.3	125	160.8*
Conference paper	7	808	115.4	95	47.2
Review	4	810	202.5*	209.5*	96.6
Note	0	0	0	0	-
Book	7	1011	144.4	129	63.1
Editorial	1	376	376	376	-

Table 3. shows digital learning topics, most of the publications are in the form of articles (n=81). Digital learning has been totally cited 14,206. The standard deviation is quite high, namely digital learning (n=160.8).

Table 4. The source titles of top 100 highest cited publication in the last 30 years

Source Title	TD	TC
Computers and Education	13	2983
Educational Technology and Society	4	415
Journal of Computer Assisted Learning	3	565
Journal of Research on Technology in Education	3	530
Language and Learning in the Digital Age	3	468
Geoderma	3	386
ReCALL	3	325
Internet and Higher Education	2	1008
Rethinking Pedagogy for a Digital Age: Designing and Delivering E-Learning	2	343
Learning, Media and Technology	2	264
TD = Total Documents TC = Total Citations		

Table 4. shows that the source titles of digital learning are varied and we can see that the source title which produces the most digital learning topics, namely Computers and Education (n=13 documents). The highest total citation is 2,983 namely source title is Computers and Education.

3.4. The Year Wise Distribution of Top 100 Highest Cited Publications in the Last 30 Years

Table 5. contains information on the distribution of the top 100 cited publications on the topics of digital learning. The range of data used is from 1992 to 2021.

Table 5. The year wise distribution of top 100 highest cited publications in the last 30 years

Year	Citable Year	Digital Learning			
		TC	TD	ACPP	ACPPY
1992	30	0	0	0	0
1993	29	0	0	0	0
1994	28	0	0	0	0
1995	27	215	2	107.5	3.9
1996	26	0	0	0	0
1997	25	0	0	0	0
1998	24	0	0	0	0
1999	23	0	0	0	0
2000	22	0	0	0	0
2001	21	420	2	210	10
2002	20	0	0	0	0
2003	19	0	0	0	0
2004	18	454	2	227	12.6
2005	17	1237	4	309.2*	18.2
2006	16	270	2	135	8.4
2007	15	891	5	178.2	11.8
2008	14	869	5	173.8	12.4
2009	13	2282	7	326	25.1
2010	12	421	3	140.3	11.6
2011	11	932	7	133.1	12.1
2012	10	1327	10	132.7	13.3
2013	9	1199	7	171.3	19
2014	8	894	8	111.7	13.9
2015	7	443	4	110.7	15.8
2016	6	2699*	11*	245.4	40.9
2017	5	567	4	141.7	28.4
2018	4	881	6	146.8	36.7
2019	3	884	9	98.2	32.7
2020	2	326	2	163	81.5*
2021	1	0	0	0	0
*The Highest Number					

This information can be used to see in what year the top 100 cited publications were produced on the topic. From this study it was found that the highest year is 2016 (n=11 documents). In addition, from this study it was found that the highest year is 2016 (n=2,699 citations). The highest average citation per paper per year in 2020 is 81,5.

3.5. Literature Review of Digital Learning to Physics Learning

Table 6. contains the results of the literature review by taking into account the quartiles, citations, and findings to provide recommendations regarding the selected paper.

Table 6. Top 5 highest cited paper showing contribution of digital learning to physics learning

Author	SJR	Citation	Findings
Anderson, J. L., & Barnett, M. [26]	1,03 (Q1)	46	Digital learning with game simulations has a positive impact on the learning outcomes of junior high school students in physics learning.
Sengupta, P., Krinks, K. D., & Clark, D. B. [27]	4,06 (Q1)	22	The results of the study show that the combination of using digital learning fosters student physics learning motivation.
Melo, M. [28]	0,54 (Q2)	4	The use of digital learning 4C/ID model in physics content to students has a positive impact on learning outcomes.
Euler, E., Prytz, C., & Gregorcic, B. [29]	0,34 (Q3)	1	Digital learning using the Algodoo application gives students the opportunity to explore physics learning materials for free and able to attract students' attention in learning.
Sukarno & Widdah, M.E. [30]	0,49 (Q2)	1	Students' metacognitive and digital literacy skills increase in physics learning.

The ranking system of reputable journals based on the subject or category of the related journal field is also called quartiles [31]. From these results, it can be seen that the topic of digital learning has the highest citation 46, thus, research related to digital learning in physics will have a lot of potentials, and its novelty will be quite high. Digital learning tends to take advantage of interactive learning applications to increase student motivation and learning outcomes [32].

3.6. Advantage and Disadvantage of Digital Learning to Physics Learning

Table 7. Discussion about digital learning

Discussion	Digital Learning
Meaning	Learning media that can be done digitally without having to wait for internet access to start.
Characteristics	▪ Some digital learning can be accessed without internet ▪ Not tied to face-to-face or non-face-to-face learning ▪ More towards the learning media
Advantage	Can be used in various places, can trigger students to think creatively and innovatively
Disadvantage	Can lead to dependence on digital tools so that it can cause laziness in students

From table 7., broadly speaking, it can be concluded that digital learning has advantages in flexibility and types of media that utilize sophisticated digital tools. While the disadvantages have an impact on students' lifestyles which can become dependent on digital learning media.

3.7. Analysis of the Important Role of Interactive Learning in Physics Based on Digital Learning Research

Learning physics still tends to be difficult for most students to understand. Physics learning needs to be set more interactively for students. The use of interactive learning media can be integrated using a combination of video, graphics, text, and sound. Digital learning by applying interactive virtual reality can deepen students' understanding of physics material. In addition, through good quality worksheets in digital learning can be improved the students' critical thinking skills in learning physics. Practical activities can play an important role in engaging students with the world of science, especially when using digital tools. So, it can be concluded that interactive learning can improve student learning outcomes [33].

The majority of students in the 21st century is proficient in advanced technology and are adaptable. For example, the use of interactive modules is also very important to apply because, according to research [34], digital learning of physics with interactive modules shows compatibility and a positive impact. Since the last three years, the world has been affected by the pandemic, so academic units must also think about effective learning methods that can still improve student achievement. Therefore, interactive learning in physics is starting to be more widely applied. One of them is by using interactive multimedia, which is able to improve students' understanding of concepts [35]. Interactive learning plays an important role in deepening the concept of physics and making the learning atmosphere more interesting even through digital learning.

4. Conclusion

Research results analysis using bibliometric studies and literature reviews related to digital learning research get several conclusions. The conclusion is that the trend of digital learning topics is increased steadily, from 2014 to 2021. The most commonly used keywords are digital age, and digital literacy. The United States (US) has made the highest contribution over the last thirty years on digital learning. The author with the highest citation on

digital learning is M. Papastergiou from Greece. The type of document that is often published by the author is in the form of articles. The highest source titles digital learning is the paper *Computers and Education*. The highest average citation per paper per year is in 2020 where digital learning (n=81,5). The digital learning topics contribute to learning physics. From the explanation above, the future research related to digital learning in physics will have a lot of potentials, and its novelty will be quite high. The important role of interactive learning in physics is to improve student learning outcomes, train critical thinking skills, deepen understanding of concepts and make learning more interesting. The advantages of digital learning is in flexibility such as the learning process can be carried out even though it is not face-to-face, reducing learning hours and types of media that utilize sophisticated digital tools. While the disadvantages have an impact on students' lifestyles which can become dependent on digital learning media and because it's using the internet network, which requires costs and a strong signal because not all areas have a strong network connection.

The implication of this research is to show the trend of publication of digital learning topics so that future researchers can show more benefits related to these topics. With this article, researchers can find out the strengths and weaknesses of digital learning topic and can find updates for future research. The limitation of the study is that some research results at Scopus are limited to full access. More intensively, further research can be carried out by comparing other learning systems applied in physics learning.

Acknowledgement

The author's gratitude goes to the Direktorat Jenderal Pendidikan Tinggi, Riset, dan Teknologi; Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, Indonesia who has supported funding in Penelitian Dasar Unggulan Perguruan Tinggi - DRTPM 2022 [Contract Number: 29551/UN38.9/LK.04.00/2022].

References

[1]. Dias Canedo, E., Aymoré Martins, V., Coelho Ribeiro, V., dos Reis, V. E., Carvalho Chaves, L. A., Machado Gravina, R., ... & de Sousa Jr, R. T. (2021). Development and Evaluation of an Intelligence and Learning System in Jurisprudence Text Mining in the Field of Competition Defense. *Applied Sciences*, *11*(23), 11365. https://doi.org/10.3390/app112311365

[2]. Hsu, F. H., Lin, I. H., Yeh, H. C., & Chen, N. S. (2022). Effect of Socratic Reflection Prompts via video-based learning system on elementary school students' critical thinking skills. *Computers & Education*, *183*, 104497. https://doi.org/10.1016/j.compedu.2022.104497

[3]. Hassan, T. (2022). A Global Overview on COVID-19 Pandemic: Vaccines and New Variants. *Pakistan Journal of Medicine and Dentistry*, *11*(1), 89-93. https://doi.org/10.36283/PJMD11-1/015

[4]. Donham, C., Barron, H. A., Alkhouri, J. S., Changaran Kumarath, M., Alejandro, W., Menke, E., & Kranzfelder, P. (2022). I will teach you here or there, I will try to teach you anywhere: Perceived supports and barriers for emergency remote teaching during the COVID-19 pandemic. *International journal of STEM education*, *9*(1), 1-25.

[5]. Temelli, D. (2022). Reflexes of international organizations regarding education in the covid-19 pandemic process and comparing implementations in turkey. *Milli Egitim*, 51(233), 887-909. https://doi.org/10.37669/milliegitim.788444

[6]. Schirmel, J. (2021). COVID-19 Pandemic Turns Life-Science Students into 'Citizen Scientists': Data Indicate Multiple Negative Effects of Urbanization on Biota. Sustainability 2021, 13, 2992.

[7]. Olmes, G. L., Zimmermann, J. S. M., Stotz, L., Takacs, F. Z., Hamza, A., Radosa, M. P., ... & Radosa, J. C. (2021). Students' attitudes toward digital learning during the COVID-19 pandemic: A survey conducted following an online course in gynecology and obstetrics. *Archives of Gynecology and Obstetrics*, *304*(4), 957-963. https://doi.org/10.1007/s00404-021-06131-6

[8]. Guppy, N., Verpoorten, D., Boud, D., Lin, L., Tai, J., & Bartolic, S. (2022). The post-COVID-19 future of digital learning in higher education: Views from educators, students, and other professionals in six countries. *British Journal of Educational Technology*. https://doi.org/10.1111/bjet.13212

[9]. Addae, D., Amponsah, S., & Gborti, B. J. (2022). COVID-19 Pandemic and the Shift to Digital Learning: Experiences of Students in a Community College in Ghana. *Community College Journal of Research and Practice*, *46*(1-2), 101-112. https://doi.org/10.1080/10668926.2021.1972364

[10]. Poluakan, C., & Katuuk, D. (2021). PIMCA: a new alternativesto physics learning model. *Journal of Physics: Conference Series*, 2165, 1-6.

[11]. Pavin Ivanec, T. (2022). The Lack of Academic Social Interactions and Students' Learning Difficulties during COVID-19 Faculty Lockdowns in Croatia: The Mediating Role of the Perceived Sense of Life Disruption Caused by the Pandemic and the Adjustment to Online Studying. *Social Sciences*, *11*(2), 42.

[12]. Vieyra, R., & Himmelsbach, J. (2022). Teachers' Disciplinary Boundedness in the Implementation of Integrated Computational Modeling in Physics. *Journal of Science Education and Technology*, *31*(2), 153-165. https://doi.org/10.1007/s10956-021-09938-9

[13]. Dewantara, D., Sofianto, E. W. N., Misbah, & Munawaroh, D. (2021). Physics e-module: A review and bibliometric analysis. *Journal of Physics: Conference Series*, 2104, 1-7. https://doi.org/10.1088/1742-6596/2104/1/012008

[14]. 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), 136-154. https://doi.org/10.3991/ijim.v15i08.20415

[15]. Wang, J., Shen, L., & Zhou, W. (2021). A bibliometric analysis of quantum computing literature: mapping and evidences from scopus. *Technology Analysis & Strategic Management*, *33*(11), 1347-1363. https://doi.org/10.1080/09537325.2021.1963429

[16]. Kamaruzzaman, W. M. I. W. M., Nasir, N. A. M., Hamidi, N. A. S. M., Yusof, N., Shaifudin, M. S., Suhaimi, A. M. A. A. M., ... & Ghazali, M. S. M. (2022). 25 years of progress on plants as corrosion inhibitors through a bibliometric analysis using the Scopus database (1995–2020). *Arabian Journal of Chemistry*, *15*(4), 103655. https://doi.org/10.1016/j.arabjc.2021.103655

[17]. Kulkanjanapiban, P., & Silwattananusarn, T. (2022). Comparative analysis of Dimensions and Scopus bibliographic data sources: an approach to university research productivity. *International Journal of Electrical and Computer Engineering (IJECE)*, *12*(1), 706-720. https://doi.org/10.11591/ijece.v12i1.pp706-720

[18]. Putri, C. R., Soleh, S. M., Saregar, A., Anugrah, A., & Susilowati, N. E. (2021, February). Bibliometric analysis: Augmented reality-based physics laboratory with VOSviewer software. In *Journal of Physics: Conference Series* (Vol. 1796, No. 1, p. 012056). IOP Publishing. https://doi.org/10.1088/1742-6596/1796/1/012056

[19]. Nishioka, C., & Färber, M. (2020, August). Trends of Publications' Citations and Altmetrics Based on Open Access Types. In *Proceedings of the ACM/IEEE Joint Conference on Digital Libraries in 2020* (pp. 503-504). https://doi.org/10.1145/3383583.3398584

[20]. Soehartono, A. M., Yu, L. G., & Khor, K. A. (2022). Essential signals in publication trends and collaboration patterns in global Research Integrity and Research Ethics (RIRE). *Scientometrics*, 1-11. https://doi.org/10.1007/s11192-022-04400-y

[21]. Sousa, M. J., & Rocha, Á. (2018). Special section on "emerging trends and challenges in digital learning". *Universal Access in the Information Society*, *17*(4), 675-677. https://doi.org/10.1007/s10209-017-0572-6

[22]. Zhao, L., Cao, C., Li, Y., & Li, Y. (2022). Determinants of the digital outcome divide in E-learning between rural and urban students: Empirical evidence from the COVID-19 pandemic based on capital theory. *Computers in Human Behavior*, *130*, 107177. https://doi.org/10.1016/j.chb.2021.107177

[23]. Ali, J., Jusoh, A., Idris, N., Abbas, A. F., & Alsharif, A. H. (2021). Nine Years of Mobile Healthcare Research: A Bibliometric Analysis. *iJOE*, *17*(10), 145. https://doi.org/10.3991/ijoe.v17i10.25243

[24]. Effendi, D. N., Anggraini, W., Jatmiko, A., Rahmayanti, H., Ichsan, I. Z., & Rahman, M. M. (2021, February). Bibliometric analysis of scientific literacy using VOS viewer: Analysis of science education. In *Journal of Physics: Conference Series* (Vol. 1796, No. 1, p. 012096). IOP Publishing. https://doi.org/10.1088/1742-6596/1796/1/012096

[25]. Pristianti, M. C. (2022). Top 100 Cited Research of Confirmatory Factor Analysis (CFA) in Education From 2012 to 2021. *International Journal of Current Educational Research*, *1*(1), 68-83. https://doi.org/10.53621/ijocer.v1i1.140

[26]. Anderson, J. L., & Barnett, M. (2013). Learning physics with digital game simulations in middle school science. *Journal of science education and technology*, *22*(6), 914-926. https://doi.org/10.1007/s10956-013-9438-8

[27]. Sengupta, P., Krinks, K. D., & Clark, D. B. (2015). Learning to deflect: Conceptual change in physics during digital game play. *Journal of the Learning Sciences*, *24*(4), 638-674. http://dx.doi.org/10.1080/10508406.2015.1082912

[28]. Melo, M. (2018). The 4C/ID-Model in Physics Education: Instructional Design of a Digital Learning Environment to Teach Electrical Circuits. *International Journal of Instruction*, *11*(1), 103-122. https://doi.org/10.12973/iji.2018.1118a

[29]. Euler, E., Prytz, C., & Gregorcic, B. (2020). Never far from shore: productive patterns in physics students' use of the digital learning environment Algodoo. *Physics Education*, *55*(4), 045015. https://doi.org/10.1088/1361-6552/ab83e7

[30]. Sukarno, S., & El Widdah, M. (2020). The Effect of Studentsâ€™ Metacognition and Digital Literacy in Virtual Lectures during the Covid-19 Pandemic on Achievement in the â€œMethods and Strategies on Physics Learningâ€ Course. *Jurnal Pendidikan IPA Indonesia*, *9*(4), 477-488. https://doi.org/10.15294/jpii.v9i4.25332

[31]. Arianto, M. A., & Basthomi, Y. (2021). The authors' research gap strategies in ELT research article introductions: Does scopus journal quartile matter?. *Journal of Language and Linguistic Studies*, *17*(4), 1743-1759. https://doi.org/10.52462/jlls.127

[32]. Engerman, J. A., & Otto, R. F. (2021). The shift to digital: designing for learning from a culturally relevant interactive media perspective. *Educational Technology Research and Development*, *69*(1), 301-305. https://doi.org/10.1007/s11423-020-09889-9

[33]. Balaton, M., Cavadas, J., Carvalho, P. S., & Lima, J. J. G. (2021). Programming Ozobots for teaching astronomy. *Physics Education*, *56*(4), 045018. https://doi.org/10.1088/1361-6552/abfb44

[34]. Wongsuwan, W., Huntula, J., & Liu, C. C. (2022). The interactive computer simulation and learning activity for facilitating students' conceptual understanding on the buoyant force through the CoSci learning platform. In *16th Siam Physics Congress, SPC 2021*. https://doi.org/10.1088/1742-6596/2145/1/012075

[35]. Susilowati, N. E., & Samsudin, A. (2021, November). What do physics teachers need? A need analysis of interactive multimedia to train creative thinking in static fluid. In *Journal of Physics: Conference Series* (Vol. 2098, No. 1, p. 012029). IOP Publishing. https://doi.org/10.1088/1742-6596/2098/1/012029

Digital Learning Research in the Last 30 Years: Important Role of Interactive Learning in Physics

Binar Kurnia Prahani [1], Mila Candra Pristianti [1], Budi Jatmiko [1], Tan Amelia [2], Firmanul Catur Wibowo [3]

[1] *Universitas Negeri Surabaya, Surabaya, Indonesia*
[2] *Universitas Dinamika, Surabaya, Indonesia*
[3] *Universitas Negeri Jakarta, Jakarta, Indonesia*

Abstract **– The aim is to analyze top 100 highest citations of digital learning research topics and the important role of interactive learning in physics in 1992-2021. This study uses bibliometric analysis and literature review. The trend of digital learning topics is increasing steadily, from 2014 to 2021. Digital learning shows an excellent contribution to physics learning. The important role of interactive learning in physics is to improve student learning outcomes, deepen understanding and make learning more interesting. More intensively, further research can be carried out by comparing other learning systems applied in physics learning.**

Keywords **– bibliometric, digital learning, education, physics learning.**

1. Introduction

Various kinds of learning systems have been applied according to surrounding conditions, the example is digital learning.

DOI: 10.18421/TEM113-46
https://doi.org/10.18421/TEM113-46

Corresponding author: Binar Kurnia Prahani,
Universitas Negeri Surabaya, Indonesia.
Email: binarprahani@unesa.ac.id

Received: 10 May 2022.
Revised: 06 August 2022.
Accepted: 12 August 2022.
Published: 29 August 2022.

The development of learning systems must pay attention to the ease of adaptation and transformation [1], [2]. Learning development can be done by combining organizational learning theory and general systems theory.

There are many impacts of the covid-19 pandemic, one of which is in the world of education. One of the updates from the covid-19 case on October 10, 2021, all countries have reported 219 million positive cases of covid-19 with 4.55 million deaths [3]. With the danger that threatens, many countries are trying to make learning sustainable [4]. Efforts are made to organize healthy learning during the covid-19 pandemic crisis [5]. The covid-19 outbreak has led to the closure of schools and colleges, so educational institutions are designed to be more flexible, namely the learning process can be carried out even though it is not face-to-face, reducing learning hours and utilizing digital platforms. Research conducted by Schirmel [6], Neil [7], and David [8] concluded that during the covid-19 pandemic, student responses showed good acceptance of digital learning. Students accepted and adapted easily to digital technology during the covid-19 pandemic.

Physics learning is closely related to natural phenomena and experimental activities. The flexibility of physics learning can be done using digital technology or without it [9]. By learning physics through digital learning students are challenged to be more independent, must easily adapt and be willing to learn. However, there are shortcomings in the implementation of digital learning, namely some places have limited access to digital media and potential dependence on digital technology [10]. Mentoring and supervision by physics teachers will determine the success of digital learning [11].

From the existing studies, there is still no discussion that shows the contribution of digital learning in physics learning and the important role of

interactive learning in physics. Some studies tend to discuss digital learning, but to show the right data regarding the analysis, bibliometric studies and literature reviews are needed. Bibliometric analysis is a method to provide knowledge regarding the growth and flow of literature in a particular publication field [12]. This bibliometric study uses empirical data to track existing publications [13]. This study can analyze the distribution of manuscripts sorted by country, source, year and more [14].

This research was carried out with an explanation of the importance of digital learning as well as the existing shortcomings. The aim is to analyze top 100 highest citations of digital learning research topics, and the important role of interactive learning in physics from 1992 to 2021. For analysis are used bibliometrics and also literature review. The objective research included:

1. Analysis of the trend of digital learning publications from the last thirty years.
2. Identifying the most widely used keywords, the country and author that contribute the most to the publication of digital learning in the last thirty years.
3. Identifying document types and source titles for digital learning from the last thirty years.
4. Identifying the year wise distribution of the top 100 cited digital learning publications from the last thirty years.
5. Identifying the contribution of digital learning in physics learning over the last thirty years.
6. Identifying the advantages and disadvantages of digital learning.
7. Analysis of the important role of interactive learning in physics.

2. Methods

This study uses bibliometric analysis and literature review. The data used in this study were taken from Scopus. Scopus is well-known for its largest database of publications in various fields including academic fields such as natural sciences, computing and others [15], [16]. Data from Scopus can be adjusted according to the needs of the year, title, country, keywords, and so on [17]. In addition, this study uses a literature review from previous studies as a reinforcement of research data.

Research data was taken on April 1, 2022. The data in Scopus is selected based on the keywords you want to search for. In this study, the keyword selection stage was carried out twice, the first regarding digital learning. Furthermore, the second keywords are connected with physics learning to find the contribution of digital learning, more details can be seen in Figure 1. The data was obtained in the form of .csv which was then analyzed using Microsoft excel and .ris which was analyzed using VOSViewer [18].

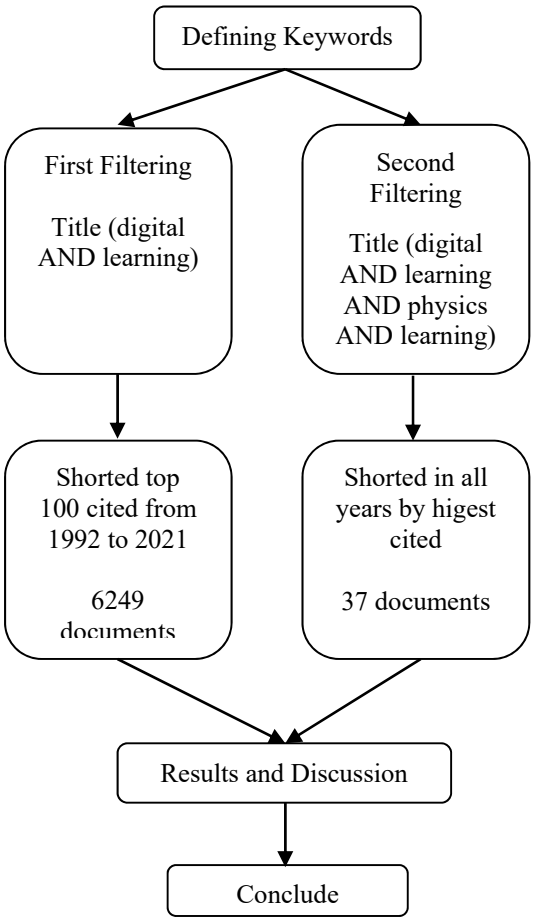

Figure 1. Flowchart for the keyword filtering

3. Results and Discussion

3.1. Publication Trend in the Last 30 Years

From Figure 2., we can see the trend of publications related to digital learning. The trend of publication is an important aspect to pay attention to and follow up [19]. Considering that publications must be in accordance with current conditions, which mean the development of a topic is determined from the trend of publications each year [20].

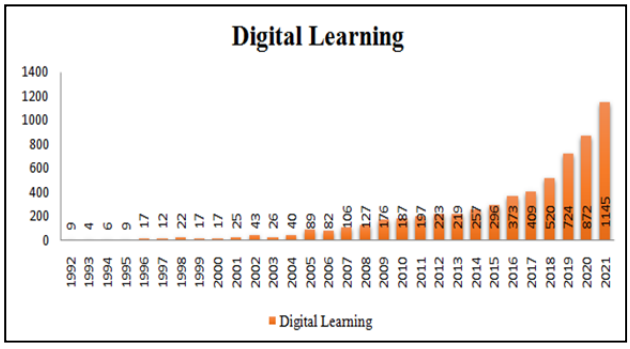

Figure 2. Digital learning publication trends

The highest digital learning publication was in 2021 with 1145 documents and the lowest in 1993 with 4 documents. Digital learning publications began to increase steadily, from 2014 to 2021. The highest increase occurred in 2021 with as many as 273 documents from 2020. The researchers tend to be interested in raising the topic of digital learning [21]. This is in line with the fact that the majority of education in the world has used digital learning due to the emergence of the Covid-19 pandemic [22]. So that research related to digital learning has high potential for future research.

3.2. Visualization of the Most Used Keywords, Top Countries and Top Authors Who Contributed the Most

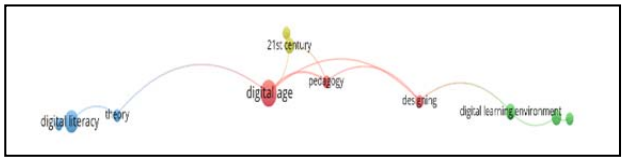

Figure 3. The keywords visualization of digital learning

Figure 3. shows the keyword visualization using VOSViewer. Keywords can describe the subject matter in a publication [23]. For digital learning topics, the most commonly used keyword is "digital age" which has 8 occurrences and "digital literacy" has 6 occurrences.

Table 1. Comparison of the top 10 countries with the most publications in the last thirty years

Top 10 countries	Publications
United States	1,359
United Kingdom	460
China	422
Germany	347
Australia	319
Taiwan	306
Spain	281
Indonesia	221
Canada	208
India	187

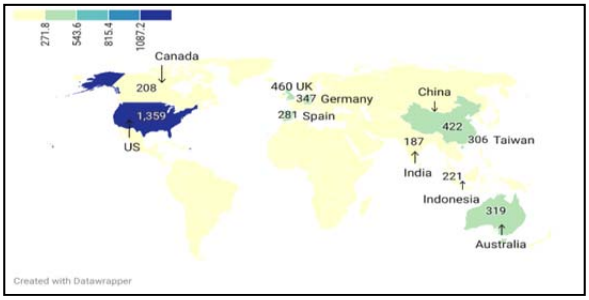

Figure 4. Top 10 Countries with publications about digital learning

From Table 1. and Figure 4., it can be concluded that the United States produced the highest number of papers over the last thirty years on the topic of digital learning. There are five countries that consistently occupy the top 10 on all publication topics related to digital learning including the United States, China, United Kingdom, Australia and Spain. To identify the author who has the most publications on each topic of digital learning, we were using VOS viewer and Microsoft Excel analysis. The results of the Microsoft Excel analysis are shown in Table 2.

Table 2. The top 10 author with the highest citations in the last thirty years

Author	Total Citations	Country
M. Papastergiou	1,880	Greece
K. Kiili	1,978	Finland
C.M. Greenhow	2,509	United States
A.R. Janowczyk	1,269	United States
D.B. Clark	3,069	Canada
A. Madabhushi	14,845*	United States
B. Gros	660	Spain
S. Erhel	429	France
A. Sadik	367	Egypt
B.Q. Huynh	590	United States

Table 2. shows the top 10 authors from the highest citations for the topic of digital learning, M. Papastergiou from Greece. Meanwhile, the highest total citation was owned by A. Madabhushi from the United States. To find out which writers on digital learning topics produce the most digital learning papers and who are most connected to other authors, we can use a software called VOSViewer. With VOSViewer we can identify the classification of top authors [24]. The grouping and connection of each author is indicated by the presence of clusters [25]. The first results of the digital learning topic are divided into 3 clusters, namely red (n=5), green (4), blue (n=2). H. Beetham is the main author because he has 3 documents with 2 total links strength which is more than any other author.

3.3. The Document Types and Source Titles of Top 100 Highest Cited Publications in the Last 30 Years

Table 3. The document types of top 100 highest cited digital learning publication in the last 30 years

Document Type	Freq-uency	Cited	Mean	Med-ian	SD
Article	81*	14206*	175.3	125	160.8*
Conference paper	7	808	115.4	95	47.2
Review	4	810	202.5*	209.5*	96.6
Note	0	0	0	0	-
Book	7	1011	144.4	129	63.1
Editorial	1	376	376	376	-

Table 3. shows digital learning topics, most of the publications are in the form of articles (n=81). Digital learning has been totally cited 14,206. The standard deviation is quite high, namely digital learning (n=160.8).

Table 4. The source titles of top 100 highest cited publication in the last 30 years

Source Title	TD	TC
Computers and Education	13	2983
Educational Technology and Society	4	415
Journal of Computer Assisted Learning	3	565
Journal of Research on Technology in Education	3	530
Language and Learning in the Digital Age	3	468
Geoderma	3	386
ReCALL	3	325
Internet and Higher Education	2	1008
Rethinking Pedagogy for a Digital Age: Designing and Delivering E-Learning	2	343
Learning, Media and Technology	2	264
TD = Total Documents TC = Total Citations		

Table 4. shows that the source titles of digital learning are varied and we can see that the source title which produces the most digital learning topics, namely Computers and Education (n=13 documents). The highest total citation is 2,983 namely source title is Computers and Education.

3.4. The Year Wise Distribution of Top 100 Highest Cited Publications in the Last 30 Years

Table 5. contains information on the distribution of the top 100 cited publications on the topics of digital learning. The range of data used is from 1992 to 2021.

Table 5. The year wise distribution of top 100 highest cited publications in the last 30 years

Year	Citable Year	Digital Learning			
		TC	TD	ACPP	ACPPY
1992	30	0	0	0	0
1993	29	0	0	0	0
1994	28	0	0	0	0
1995	27	215	2	107.5	3.9
1996	26	0	0	0	0
1997	25	0	0	0	0
1998	24	0	0	0	0
1999	23	0	0	0	0
2000	22	0	0	0	0
2001	21	420	2	210	10
2002	20	0	0	0	0
2003	19	0	0	0	0
2004	18	454	2	227	12.6
2005	17	1237	4	309.2*	18.2
2006	16	270	2	135	8.4
2007	15	891	5	178.2	11.8
2008	14	869	5	173.8	12.4
2009	13	2282	7	326	25.1
2010	12	421	3	140.3	11.6
2011	11	932	7	133.1	12.1
2012	10	1327	10	132.7	13.3
2013	9	1199	7	171.3	19
2014	8	894	8	111.7	13.9
2015	7	443	4	110.7	15.8
2016	6	2699*	11*	245.4	40.9
2017	5	567	4	141.7	28.4
2018	4	881	6	146.8	36.7
2019	3	884	9	98.2	32.7
2020	2	326	2	163	81.5*
2021	1	0	0	0	0
*The Highest Number					

This information can be used to see in what year the top 100 cited publications were produced on the topic. From this study it was found that the highest year is 2016 (n=11 documents). In addition, from this study it was found that the highest year is 2016 (n=2,699 citations). The highest average citation per paper per year in 2020 is 81,5.

3.5. Literature Review of Digital Learning to Physics Learning

Table 6. contains the results of the literature review by taking into account the quartiles, citations, and findings to provide recommendations regarding the selected paper.

Table 6. Top 5 highest cited paper showing contribution of digital learning to physics learning

Author	SJR	Citation	Findings
Anderson, J. L., & Barnett, M. [26]	1,03 (Q1)	46	Digital learning with game simulations has a positive impact on the learning outcomes of junior high school students in physics learning.
Sengupta, P., Krinks, K. D., & Clark, D. B. [27]	4,06 (Q1)	22	The results of the study show that the combination of using digital learning fosters student physics learning motivation.
Melo, M. [28]	0,54 (Q2)	4	The use of digital learning 4C/ID model in physics content to students has a positive impact on learning outcomes.
Euler, E., Prytz, C., & Gregorcic, B. [29]	0,34 (Q3)	1	Digital learning using the Algodoo application gives students the opportunity to explore physics learning materials for free and able to attract students' attention in learning.
Sukarno & Widdah, M.E. [30]	0,49 (Q2)	1	Students' metacognitive and digital literacy skills increase in physics learning.

The ranking system of reputable journals based on the subject or category of the related journal field is also called quartiles [31]. From these results, it can be seen that the topic of digital learning has the highest citation 46, thus, research related to digital learning in physics will have a lot of potentials, and its novelty will be quite high. Digital learning tends to take advantage of interactive learning applications to increase student motivation and learning outcomes [32].

3.6. Advantage and Disadvantage of Digital Learning to Physics Learning

Table 7. Discussion about digital learning

Discussion	Digital Learning
Meaning	Learning media that can be done digitally without having to wait for internet access to start.
Characteristics	▪ Some digital learning can be accessed without internet ▪ Not tied to face-to-face or non-face-to-face learning ▪ More towards the learning media
Advantage	Can be used in various places, can trigger students to think creatively and innovatively
Disadvantage	Can lead to dependence on digital tools so that it can cause laziness in students

From Table 7., broadly speaking, it can be concluded that digital learning has advantages in flexibility and types of media that utilize sophisticated digital tools. While the disadvantages have an impact on students' lifestyles which can become dependent on digital learning media.

3.7. Analysis of the Important Role of Interactive Learning in Physics Based on Digital Learning Research

Learning physics still tends to be difficult for most students to understand. Physics learning needs to be set more interactively for students. The use of interactive learning media can be integrated using a combination of video, graphics, text, and sound. Digital learning by applying interactive virtual reality can deepen students' understanding of physics material. In addition, through good quality worksheets in digital learning can be improved the students' critical thinking skills in learning physics. Practical activities can play an important role in engaging students with the world of science, especially when using digital tools. So, it can be concluded that interactive learning can improve student learning outcomes [33].

The majority of students in the 21st century is proficient in advanced technology and are adaptable. For example, the use of interactive modules is also very important to apply because, according to research [34], digital learning of physics with interactive modules shows compatibility and a positive impact. Since the last three years, the world has been affected by the pandemic, so academic units must also think about effective learning methods that can still improve student achievement. Therefore, interactive learning in physics is starting to be more widely applied. One of them is by using interactive multimedia, which is able to improve students' understanding of concepts [35]. Interactive learning plays an important role in deepening the concept of physics and making the learning atmosphere more interesting even through digital learning.

4. Conclusion

Research results analysis using bibliometric studies and literature reviews related to digital learning research get several conclusions. The conclusion is that the trend of digital learning topics is increased steadily, from 2014 to 2021. The most commonly used keywords are digital age, and digital literacy. The United States (US) has made the highest contribution over the last thirty years on digital learning. The author with the highest citation on

digital learning is M. Papastergiou from Greece. The type of document that is often published by the author is in the form of articles. The highest source titles digital learning is the paper *Computers and Education*. The highest average citation per paper per year is in 2020 where digital learning (n=81,5). The digital learning topics contribute to learning physics. From the explanation above, the future research related to digital learning in physics will have a lot of potentials, and its novelty will be quite high. The important role of interactive learning in physics is to improve student learning outcomes, train critical thinking skills, deepen understanding of concepts and make learning more interesting. The advantages of digital learning is in flexibility such as the learning process can be carried out even though it is not face-to-face, reducing learning hours and types of media that utilize sophisticated digital tools. While the disadvantages have an impact on students' lifestyles which can become dependent on digital learning media and because it's using the internet network, which requires costs and a strong signal because not all areas have a strong network connection.

The implication of this research is to show the trend of publication of digital learning topics so that future researchers can show more benefits related to these topics. With this article, researchers can find out the strengths and weaknesses of digital learning topic and can find updates for future research. The limitation of the study is that some research results at Scopus are limited to full access. More intensively, further research can be carried out by comparing other learning systems applied in physics learning.

Acknowledgement

The author's gratitude goes to the Direktorat Jenderal Pendidikan Tinggi, Riset, dan Teknologi; Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, Indonesia who has supported funding in Penelitian Dasar Unggulan Perguruan Tinggi - DRTPM 2022 [Contract Number: 29551/UN38.9/LK.04.00/2022].

References

[1]. Dias Canedo, E., Aymoré Martins, V., Coelho Ribeiro, V., dos Reis, V. E., Carvalho Chaves, L. A., Machado Gravina, R., ... & de Sousa Jr, R. T. (2021). Development and Evaluation of an Intelligence and Learning System in Jurisprudence Text Mining in the Field of Competition Defense. *Applied Sciences*, *11*(23), 11365. https://doi.org/10.3390/app112311365

[2]. Hsu, F. H., Lin, I. H., Yeh, H. C., & Chen, N. S. (2022). Effect of Socratic Reflection Prompts via video-based learning system on elementary school students' critical thinking skills. *Computers & Education*, *183*, 104497. https://doi.org/10.1016/j.compedu.2022.104497

[3]. Hassan, T. (2022). A Global Overview on COVID-19 Pandemic: Vaccines and New Variants. *Pakistan Journal of Medicine and Dentistry*, *11*(1), 89-93. https://doi.org/10.36283/PJMD11-1/015

[4]. Donham, C., Barron, H. A., Alkhouri, J. S., Changaran Kumarath, M., Alejandro, W., Menke, E., & Kranzfelder, P. (2022). I will teach you here or there, I will try to teach you anywhere: Perceived supports and barriers for emergency remote teaching during the COVID-19 pandemic. *International journal of STEM education*, *9*(1), 1-25.

[5]. Temelli, D. (2022). Reflexes of international organizations regarding education in the covid-19 pandemic process and comparing implementations in turkey. *Milli Egitim*, 51(233), 887-909. https://doi.org/10.37669/milliegitim.788444

[6]. Schirmel, J. (2021). COVID-19 Pandemic Turns Life-Science Students into 'Citizen Scientists': Data Indicate Multiple Negative Effects of Urbanization on Biota. Sustainability 2021, 13, 2992.

[7]. Olmes, G. L., Zimmermann, J. S. M., Stotz, L., Takacs, F. Z., Hamza, A., Radosa, M. P., ... & Radosa, J. C. (2021). Students' attitudes toward digital learning during the COVID-19 pandemic: A survey conducted following an online course in gynecology and obstetrics. *Archives of Gynecology and Obstetrics*, *304*(4), 957-963. https://doi.org/10.1007/s00404-021-06131-6

[8]. Guppy, N., Verpoorten, D., Boud, D., Lin, L., Tai, J., & Bartolic, S. (2022). The post-COVID-19 future of digital learning in higher education: Views from educators, students, and other professionals in six countries. *British Journal of Educational Technology*. https://doi.org/10.1111/bjet.13212

[9]. Addae, D., Amponsah, S., & Gborti, B. J. (2022). COVID-19 Pandemic and the Shift to Digital Learning: Experiences of Students in a Community College in Ghana. *Community College Journal of Research and Practice*, *46*(1-2), 101-112. https://doi.org/10.1080/10668926.2021.1972364

[10]. Poluakan, C., & Katuuk, D. (2021). PIMCA: a new alternativesto physics learning model. *Journal of Physics: Conference Series*, 2165, 1-6.

[11]. Pavin Ivanec, T. (2022). The Lack of Academic Social Interactions and Students' Learning Difficulties during COVID-19 Faculty Lockdowns in Croatia: The Mediating Role of the Perceived Sense of Life Disruption Caused by the Pandemic and the Adjustment to Online Studying. *Social Sciences*, *11*(2), 42.

[12]. Vieyra, R., & Himmelsbach, J. (2022). Teachers' Disciplinary Boundedness in the Implementation of Integrated Computational Modeling in Physics. *Journal of Science Education and Technology*, *31*(2), 153-165. https://doi.org/10.1007/s10956-021-09938-9

[13]. Dewantara, D., Sofianto, E. W. N., Misbah, & Munawaroh, D. (2021). Physics e-module: A review and bibliometric analysis. *Journal of Physics: Conference Series*, 2104, 1-7. https://doi.org/10.1088/1742-6596/2104/1/012008

[14]. 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), 136-154. https://doi.org/10.3991/ijim.v15i08.20415

[15]. Wang, J., Shen, L., & Zhou, W. (2021). A bibliometric analysis of quantum computing literature: mapping and evidences from scopus. *Technology Analysis & Strategic Management*, *33*(11), 1347-1363. https://doi.org/10.1080/09537325.2021.1963429

[16]. Kamaruzzaman, W. M. I. W. M., Nasir, N. A. M., Hamidi, N. A. S. M., Yusof, N., Shaifudin, M. S., Suhaimi, A. M. A. A. M., ... & Ghazali, M. S. M. (2022). 25 years of progress on plants as corrosion inhibitors through a bibliometric analysis using the Scopus database (1995–2020). *Arabian Journal of Chemistry*, *15*(4), 103655. https://doi.org/10.1016/j.arabjc.2021.103655

[17]. Kulkanjanapiban, P., & Silwattananusarn, T. (2022). Comparative analysis of Dimensions and Scopus bibliographic data sources: an approach to university research productivity. *International Journal of Electrical and Computer Engineering (IJECE)*, *12*(1), 706-720. https://doi.org/10.11591/ijece.v12i1.pp706-720

[18]. Putri, C. R., Soleh, S. M., Saregar, A., Anugrah, A., & Susilowati, N. E. (2021, February). Bibliometric analysis: Augmented reality-based physics laboratory with VOSviewer software. In *Journal of Physics: Conference Series* (Vol. 1796, No. 1, p. 012056). IOP Publishing. https://doi.org/10.1088/1742-6596/1796/1/012056

[19]. Nishioka, C., & Färber, M. (2020, August). Trends of Publications' Citations and Altmetrics Based on Open Access Types. In *Proceedings of the ACM/IEEE Joint Conference on Digital Libraries in 2020* (pp. 503-504). https://doi.org/10.1145/3383583.3398584

[20]. Soehartono, A. M., Yu, L. G., & Khor, K. A. (2022). Essential signals in publication trends and collaboration patterns in global Research Integrity and Research Ethics (RIRE). *Scientometrics*, 1-11. https://doi.org/10.1007/s11192-022-04400-y

[21]. Sousa, M. J., & Rocha, Á. (2018). Special section on "emerging trends and challenges in digital learning". *Universal Access in the Information Society*, *17*(4), 675-677. https://doi.org/10.1007/s10209-017-0572-6

[22]. Zhao, L., Cao, C., Li, Y., & Li, Y. (2022). Determinants of the digital outcome divide in E-learning between rural and urban students: Empirical evidence from the COVID-19 pandemic based on capital theory. *Computers in Human Behavior*, *130*, 107177. https://doi.org/10.1016/j.chb.2021.107177

[23]. Ali, J., Jusoh, A., Idris, N., Abbas, A. F., & Alsharif, A. H. (2021). Nine Years of Mobile Healthcare Research: A Bibliometric Analysis. *iJOE*, *17*(10), 145. https://doi.org/10.3991/ijoe.v17i10.25243

[24]. Effendi, D. N., Anggraini, W., Jatmiko, A., Rahmayanti, H., Ichsan, I. Z., & Rahman, M. M. (2021, February). Bibliometric analysis of scientific literacy using VOS viewer: Analysis of science education. In *Journal of Physics: Conference Series* (Vol. 1796, No. 1, p. 012096). IOP Publishing. https://doi.org/10.1088/1742-6596/1796/1/012096

[25]. Pristianti, M. C. (2022). Top 100 Cited Research of Confirmatory Factor Analysis (CFA) in Education From 2012 to 2021. *International Journal of Current Educational Research*, *1*(1), 68-83. https://doi.org/10.53621/ijocer.v1i1.140

[26]. Anderson, J. L., & Barnett, M. (2013). Learning physics with digital game simulations in middle school science. *Journal of science education and technology*, *22*(6), 914-926. https://doi.org/10.1007/s10956-013-9438-8

[27]. Sengupta, P., Krinks, K. D., & Clark, D. B. (2015). Learning to deflect: Conceptual change in physics during digital game play. *Journal of the Learning Sciences*, *24*(4), 638-674. http://dx.doi.org/10.1080/10508406.2015.1082912

[28]. Melo, M. (2018). The 4C/ID-Model in Physics Education: Instructional Design of a Digital Learning Environment to Teach Electrical Circuits. *International Journal of Instruction*, *11*(1), 103-122. https://doi.org/10.12973/iji.2018.1118a

[29]. Euler, E., Prytz, C., & Gregorcic, B. (2020). Never far from shore: productive patterns in physics students' use of the digital learning environment Algodoo. *Physics Education*, *55*(4), 045015. https://doi.org/10.1088/1361-6552/ab83e7

[30]. Sukarno, S., & El Widdah, M. (2020). The Effect of Studentsâ€™ Metacognition and Digital Literacy in Virtual Lectures during the Covid-19 Pandemic on Achievement in the â€œMethods and Strategies on Physics Learningâ€ Course. *Jurnal Pendidikan IPA Indonesia*, *9*(4), 477-488. https://doi.org/10.15294/jpii.v9i4.25332

[31]. Arianto, M. A., & Basthomi, Y. (2021). The authors' research gap strategies in ELT research article introductions: Does scopus journal quartile matter?. *Journal of Language and Linguistic Studies*, *17*(4), 1743-1759. https://doi.org/10.52462/jlls.127

[32]. Engerman, J. A., & Otto, R. F. (2021). The shift to digital: designing for learning from a culturally relevant interactive media perspective. *Educational Technology Research and Development*, *69*(1), 301-305. https://doi.org/10.1007/s11423-020-09889-9

[33]. Balaton, M., Cavadas, J., Carvalho, P. S., & Lima, J. J. G. (2021). Programming Ozobots for teaching astronomy. *Physics Education*, *56*(4), 045018. https://doi.org/10.1088/1361-6552/abfb44

[34]. Wongsuwan, W., Huntula, J., & Liu, C. C. (2022). The interactive computer simulation and learning activity for facilitating students' conceptual understanding on the buoyant force through the CoSci learning platform. In *16th Siam Physics Congress, SPC 2021*. https://doi.org/10.1088/1742-6596/2145/1/012075

[35]. Susilowati, N. E., & Samsudin, A. (2021, November). What do physics teachers need? A need analysis of interactive multimedia to train creative thinking in static fluid. In *Journal of Physics: Conference Series* (Vol. 2098, No. 1, p. 012029). IOP Publishing. https://doi.org/10.1088/1742-6596/2098/1/012029