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INSECTA
Integrative Science Education and Teaching Activity Journal
Journal homepage : https://jurnal.iainponorogo.ac.id/index.php/insecta

Article

Analysis of the Potential of Virtual Lab Research Development in Science Learning with the Bibliometric method

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ABSTRACT

The development of scientific fields is possible through communication between researchers. This communication can be established with a medium called the Scientific Journal. Through the media, each researcher searches for articles that have been researched on the same topic. So that they will easily update or develop the topic. This method is known as the bibliometric analysis method. Therefore this study aims to carry out the same analysis on the virtual lab theme. This is important in learning development, especially in science learning. The data obtained was in the form of many articles from the SCOPUS database, which several criteria had previously defined to capture them. These criteria are related to the year of publication, keywords and language selection. The application used in this study is the VOS Viewers application. The results show that research related to virtual labs in science learning is still very possible considering many limited lab facilities in some schools. However, it should be noted that virtual labs cannot replace traditional laboratories because traditional laboratories can give students hands-on practical experience. It is better if the virtual lab is considered as a supplementary to science learning.

INTRODUCTION

Natural Science defined as a systematic study of the structure and behaviour of the physical, social and natural world through observation and experimentation (Church et al., 2021; Ganien & Fauziah, 2022). The progress of Science is the key to innovation, global competitiveness, and human progress (Mormina, 2019; Raghupathi & Raghupathi, 2019). Therefore, it is crucial for the world to continue advancing in Science, for example developing new treatment methods for people with cancer and other diseases or identifying and exploring outer space (Aglietti, 2020; Debela et al., 2021; Trott & Weinberg, 2020). Learning Science can develop knowledge, and problem-solving skills and improve critical thinking to foster a desire to continue learning (Voitle et al., 2022).

Schools in Indonesia always include science material at the elementary to the middle school level. At the elementary school level, science material is packaged more simply and is readily observable by students (Mutanaffisah et al., 2021). At junior high school level, science material is delivered in an integrated manner (Chemistry, Physics, Biology) so that students can understand the basic concepts of a natural phenomenon (Hafifah & Sulistyo, 2020). Meanwhile, at the high school level, science material is discussed more precisely, and in terms of each scientific discipline. This is done by occasionally considering the development of students' cognitive abilities (Syahfitri et al., 2019). Of course, there are differences in science learning activities at each level.

Science learning activities are easy for students to accept if they are involved (Rohandi, 2019). Therefore, learning Science can be delivered through the lecture method and practicum activities (Halawa et al., 2020; Hasanah & Anfa, 2021). Practical activities are usually carried out to prove a concept or answer questions about a problem. So teachers are also required to have the ability to operate practicum tools. The advantage is when the school has adequate tools or practicum space, often called a laboratory. Science learning also promote scientific literacy with various skills to develop (Syahwati & Arif, 2022).

The laboratory at school is one of the mandatory facilities. Because that way, students can immediately practice with standardized tools so that the data obtained is more reliable. In addition, in terms of skills, much can be developed when students practice in the laboratory. Shana & Abulibdeh (2020) research shows that doing science practicums can improve students' skills in finding something, often called discovery learning. Besides that, through practicum, students also have science process skills, from making observations to concluding (Astuti et al., 2019). They will also have skills in carrying out a procedure in a systematic manner. This is obtained when students carry out practicum steps by the guidebook (Idris et al., 2022).

Moreover, the more important skills are students' thinking skills. The practicum implementation and the results obtained are able to develop students' critical or creative thinking skills. How do they draw conclusions based on the data obtained and creatively solve a problem (Idris et al., 2022; Rahayu & Eliyarti, 2019; Tanti et al., 2020). Students can receive many more benefits when learning in the laboratory, especially now that it is even easier with technology in the world of education.

The presence of technology in education provides incredible benefits to the course of the learning process. Currently, learning can be carried out anytime and anywhere. In addition, students can also access unlimited learning resources. If it is associated with laboratories, the presence of technology also contributes to this sector, namely the existence of a virtual lab. Usually, laboratories in a room can now be packaged in an application or website. So that students can do practicum without having to be in a laboratory. The advantage of this virtual is that it can reduce work errors and accidents during practicum (Maksum & Saragih, 2020). Of course, there are some drawbacks in its application, which are often constrained by technical problems, requiring students to have a device with certain specifications, and there is no direct experience in doing practicum. The use of virtual labs also cannot reach the psychomotor domain (Fatimah et al., 2020). Based on the description above, this study aims to analyze the potential for developing a virtual laboratory using bibliometric analysis. Bibliometric Analysis is the method to exploring and analyzing the information of scientific data. It enables to unpack every specific field about an article of research topic. It helps to projecting the future of the topic. The same method has been carried out by Dimas (2022), namely using the bibliometric analysis method for online Physics learning, but has not been explained specifically related to virtual lab media. So that through this article, information can be obtained regarding the novelty of the virtual laboratory research theme. The distingtion from the other article is explanation about the specific theme and the databased used, in this research the data obtained from Scopus Indexed article

METHODS

Bibliometric analysis is a citation network analysis that relies on reference lists of articles or journal publications by showing previous contributions that have influenced the development of their research (Inamdar, 2020). Even though there are various subjective reasons for someone to choose an article to be used as a reference, it is considered a measure of the article's influence. The more people cite, the greater the article's influence (Strozzi et al., 2017). Therefore, this stage analyzes and visualizes articles based on keywords, relevant authors, relevant publishing journals and the relationship paper between these elements. Trends in the development of international publications in mosquitoes were analyzed using Vos viewers software. In general, the criteria used to capture articles for analysis are shown in Table 1.

Table 1. Study selection approach

Criteria	Including	Excluding
Language used	English	Other than English
Period	2014-2020	Before 2014 dan After 2020
Database used	Scopus	Except for Scopus
Keywords	"Virtual lab"	Unpublished paper, including preceding
	Teaching Science using a virtual lab."	paper

The article obtained about 144 articles from 85 journals. Based on that data, the next analyses done with the method below
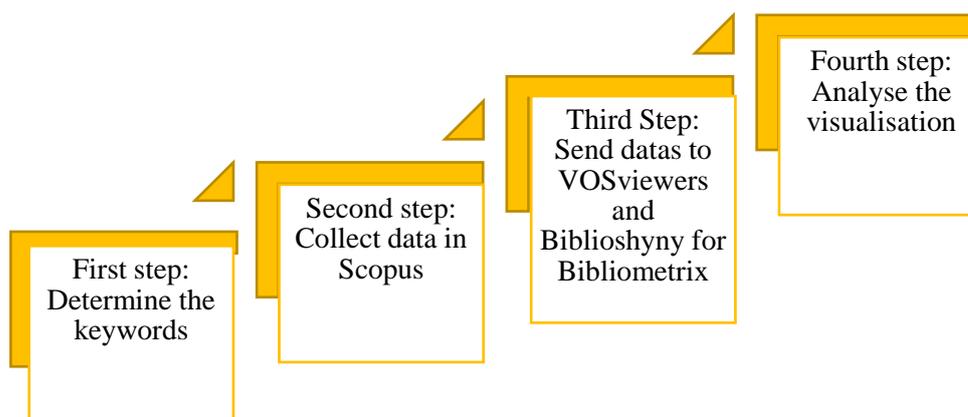
Figure 1. Research chart flow

The first step is to determine the keywords used. In this study, the keyword "virtual lab" was used. Furthermore, these keywords are used to find data in the form of many related articles in terms of titles or keywords in the abstract with "virtual lab". The following process converts the articles obtained on the VOSviewers and Biblioshyny for Bibliometrix applications. The output of the two applications is then interpreted as the research results. Tutorial to use those application as follows

1. Do a search for journal articles on Scopus using the keyword Virtual Laboratory with international journal article criteria for the past five years (2014-2020);
2. Sort keyword data from journal articles obtained using the Open Refine application. Keywords that are considered to have the same writing and meaning can be merged to make it easier to read and visualize keywords in the next process;
3. Perform data processing through the VOSviewer application to get visualization of existing keywords. In addition, we can also group keywords that can facilitate the determination of journal articles to be used in the Literature Review process. Apart

from keywords, other information such as the authors involved can be visualized and later this information can be used for data processing applied to Tableau Public

4. Perform data processing through the Tableau Public application which aims to be an alternative visualization of the information obtained. Information obtained from this application is in the form of journals, year of publication, author, many citations, and others

5. 5. Doing data processing through the Bibliometrix application, from this application we obtain library information from journal articles that are used as data;

RESULTS AND DISCUSSION

Bibliometric analysis is the part that analyzes reference management to see how a research scope develops (Dwikoranto & Widiasih, 2023). In addition, the distribution of a research topic can be found through this analysis as a reference in determining a research topic. One popularly done is Co-Word Analysis, where in principle, it looks at the relationship between two or more experts in a field of research seen from the keywords that are used. The more often a keyword appears, the closer the relationship is.

In the bibliometric analysis, several components can be described. Based on the data, the analysis can be divided into several sections, namely Keywords Analysis, Published Year Analysis, and Theme Quarter Analysis and as a complement, information on the most relevant journals and authors is also presented.

Keywords Analysis

This article analyses the keywords found in the "virtual lab" article. In general, the keywords in an article provide an overview of the contents of the article. Like what variables are studied to the methods used. Figure 2 is the result of keyword analysis in the article "virtual lab"

Figure 2. Display keyword analysis results

The data obtained in Figure 2 combines keywords that appear in articles with the virtual lab theme. The displayed words consist of different sizes and colours. Keywords larger than the others can be the words that appear most often. So based on Figure 1, the words that appear most often are e-learning, education, virtual reality, simulation and distance education. These words show that virtual labs are generally included in learning with e-learning platforms that are carrying out distance education or distance learning. This is also closely related to the implementation of the education system so that the word education also appears. Furthermore, the emergence of the word engineering education shows that the use of virtual labs is specifically for engineering majors, which in practice requires quite dense laboratory activities.

These assumptions were then confirmed by research results from 2014 to 2020, with the following results.

Table 2. Research result about virtual lab

| Year	Tittle	Results
2014	Design Virtual Learning Labs for Courses in Computational Science with the use of Cloud Computing Technologies (Dukhanov et al., 2014)	This research applies a virtual lab to solve multidisciplinary problems with the help of the cloud to distribute the required data. The advantage is that users, teachers, students or experts do not need to install other supporting applications. Just one website is enough. By implementing this virtual lab, teachers can also quickly identify the extent of student understanding.
2015	A study on the effects of model-based inquiry pedagogy on students' inquiry skills in a virtual physics lab (Wang et al., 2015)	This study designs learning by utilizing a virtual lab in Physics subjects. The results showed that students' science process skills increased, which was viewed from several aspects, namely process skills, understanding abilities, attitudes in learning, communication skills, and reflection.
2016	Measuring dental students' preference: A comparison of light microscopy and virtual microscopy as teaching tools in oral histology and pathology (Alotaibi & ALQahtani, 2016)	This study surveyed dental students in their second year by distributing questionnaires about their preference for using a microscope. The results show that 85% of students have positive feedback regarding the use of virtual microscopes. This is because using a virtual microscope allows students to manage time well and obtain images with a clear magnification. What is most preferred is that they can use a virtual microscope outside the laboratory.
2017	Virtual Reality Geographical Interactive Scene Semantics Research for Immersive Geography Learning (Lv et al., 2017)	This research develops virtual reality-based applications for use in geography learning. The developed application has the following features: real time, predictable and has a large scale so that this technology promises big data in the field of geography
2018	A virtual lab as a complement to traditional hands-on labs: Characterization of an alkaline electrolyzer for hydrogen production (Domínguez et al., 2018)	This research focuses on the use of virtual labs, namely simulations, to study the electrolysis of water for hydrogen production, even though this virtual lab is used as a complement to traditional laboratories to help students understand the basics of industrial processes. The advantage of the developed virtual lab is that it equips students with knowledge of the physical/chemical phenomena that govern the electrolysis process through the use of theoretical models to reduce practicum limitations, such as operating conditions, namely, time, temperature, and number of cells.
2019	Immersive, interactive virtual field trips promote science learning (Mead et al., 2019)	This research is an innovation in conducting field studies. Where there are many things that need to be prepared to carry out studies, virtual learning is one of the solutions. Virtual field experiences can help broaden access to field learning. Computer-based virtual field trips add adaptive feedback and richer interactivity, enabling active and more scientifically authentic learning.
2020	Virtual Laboratory as Custom E-learning Implementation and Design Solution (Sus et al., 2021)	Research is developing a virtual lab to apply e-Learning in virtual classes based on practicum settings. Virtualization-based experiments are conducted in a virtual laboratory using STEM technology and computer graphics.

Based on the results of research on virtual labs from 2014 – 2020, one thing can be seen in common, namely, the development of virtual labs is not only to replace traditional laboratories but is actually used as a complement to minimize errors and the risk of accidents that occur when working in traditional laboratories. The advantages of the virtual lab are stated by Rohim (2020) as follows:

1. Virtual labs help students connect theoretical and scientific concepts to practical laboratory techniques and skills

2. Virtual labs provide simulations that make students more involved in studying scientific phenomena;

3. Although some essential learning opportunities are not provided by virtual labs such as sensory engagement in learning, most virtual labs are developed to meet the characteristics of teaching aids;

4. The virtual laboratory shortens the preparation steps for practicum activities so that that class time can be used effectively;

5. Virtual laboratory allows students to repeat the experiment several times. In addition, the use of virtual labs also brings prospects to several important aspects of the education sector, namely financial resources, academic progress, increased simulation of computer technology, and cultural aspects.

The subsequent analysis related to keywords is analysis of keywords based on the year of publication.

Published Year Analysis

In this analysis, keywords in articles related to virtual labs are clustered based on the year the article was published. Through this analysis, information can be obtained regarding the latest research variables or those that have been used for a long time. This can help analyze opportunities in developing research related to virtual labs. The results of the analysis are presented in Figure 3
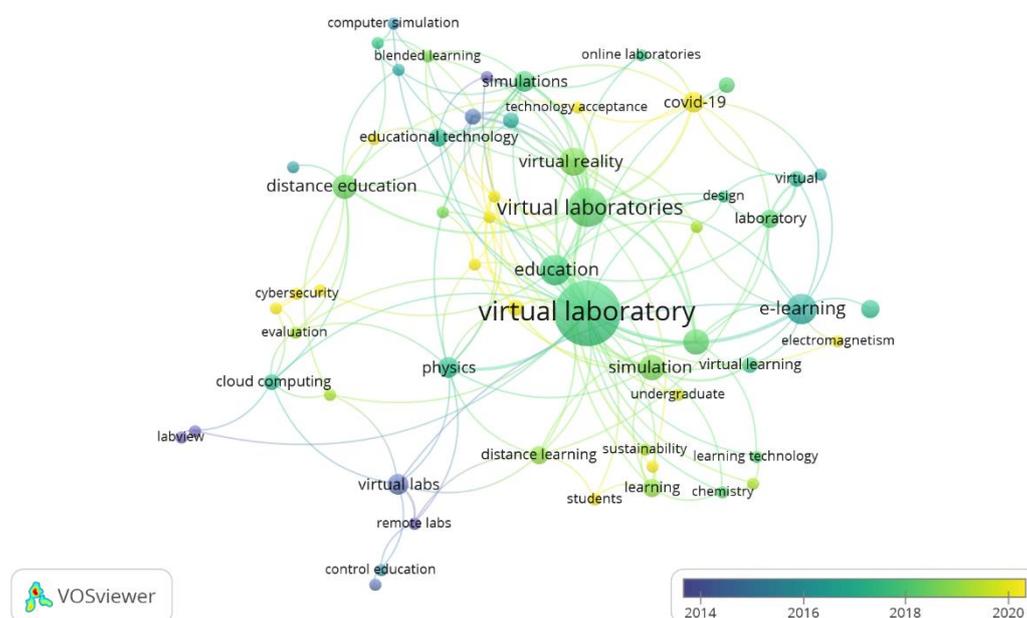
Figure 3. Keyword analysis results based on the year of publication

The data in Figure 2 is obtained from the VOS Viewers application. VOSviewer is software for building and visualizing bibliometric networks. These networks for example can include individual journals, researchers, or publications, and they can be built on citations, bibliographical merging, co-citations, or co-author relationships. The scale shown in Figure 2 provides information on the range of years from 2014 to mid-2020. The scale also provides information related to colour. The brighter the background colour for each topic, the more recent the topic is discussed in the journal article.

On this scale, the darkest area is 2014. The keywords with the darkest background colour are lab view, virtual labs, remote labs and simulations. The virtual lab research themes related

to the previously mentioned keywords are themes that have been researched since 2014. So that needs to be reconsidered when choosing this theme again. For example, Labview refers to an application used for Engineering Laboratory Virtual Instruments, a visual programming from National Instruments. In 2014, this application was used by Saeful Bahri et al., (2014), where his research designed a PC-based temperature control and monitoring system using LabView and NI-DAQ 6008 as data communication between the PC and the controlled system. This temperature control and monitoring system is a prototype for controlling the temperature of the oven chamber. Whereas in the Labview learning process, it is used to develop practicum devices using ultrasonic sensor-based springs with the Arduino and Labview applications to determine the value of the acceleration of gravity (g), this development produces products in the form of practicum tools and practicum guides (Muspa & Suwondo, 2020). Likewise, research with remote labs and simulation variables has been done a lot before, apart from being used in the fields of Science or engineering. These variables are also used in education (Amorim et al., 2014; chandra et al., 2014; Orduña et al., 2014)

Next are keywords in blue to green. The keywords in this area are in the middle, meaning they were studied extensively from 2016 to 2018. The keywords in that period were physics, blended learning, online laboratories, and cloud computing. The use of virtual labs or online laboratories is very widely used in learning that uses the blended learning method. The Blended learning method itself is a learning method that combines two or more models. Usually, a combination of online and offline learning. Klentien & Wannasawade (2016) used a blended learning method based on a learning project through a virtual science laboratory. This method leads students to understand science lessons more efficiently, allowing them to conduct experiments in a shorter time and encouraging them to make new experiments.

The last timeframe in Figure 3 shows the years 2018-2020. The colour that represents this area is green to brass. During this time, one of the visible words is Covid-19. In 2020 the government in every country issued a policy for lockdown so that all activities that previously could be carried out in person must be carried out online. Including learning activities inhe schools and the practicum process is no exception. Rafaela (2020) developed a virtual lab application that can be accessed at home during the lockdown process. Virtual labs cannot completely replace physical experiments in traditional laboratories. However, in academia, virtual and physical laboratories can work together. Especially during the COVID-19 pandemic, students can conduct experiments online without time limits, receive feedback quickly and familiarize themselves with health and safety regulations.

The bibliometric method with various modifications has been carried out. Especially on the virtual lab theme, there are 2 articles that discuss this, of which two are Scopus indexed. The first research from Raman et al., (2022) discusses the history and development of the virtual lab topic over the last 30 years. This article is more specific regarding the number of citations, authors or co-authors who have written a lot about virtual labs. In terms of analysis, this article is more specifically related to the research topic. The next article from Heradio et al., (2016) this article has been analyzed for quite a long time, namely about seven years ago when there was a research trend on virtual labs. This article discusses the virtual lab quantitatively while this article discusses it qualitatively

CONCLUSION

This article is based on bibliometric data from the VOS viewers application. After interpreting the output of the application image (data), the research theme related to virtual labs is still possible to do with various innovations. This can be considered by assuming the virtual lab is not the leading learning resource or can replace traditional laboratories but is used as a complement or supplementary to traditional laboratories. Furthermore, the fields of Science

that use a lot of virtual labs are Science, and engineering and can simply be applied in education. Virtual lab is applied to Middle School students to College Students.

The limitation of this article is that the scope analyzed is not too specific in the field of education. This is because the search engine, in this case, the Scopus database, does not differentiate virtual labs in the field of education and virtual labs in the fields of Science and engineering. Suggestions for future researchers are to use more specific keywords in order to obtain an appropriate article database.

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