Publications related to virtual laboratories during the covid 19 pandemic: A bibliometric review and analysis

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Abstract. During the COVID-19 pandemic, virtual laboratories are instrumental in learning physics concepts. A virtual laboratory is one media that can be used as a solution to carry out concept discovery activities through simulation using computer software. This article was created to explain the trend of publications related to virtual laboratories during the COVID-19 pandemic for 2020-2021 through bibliometric analysis of the literature. The papers analyzed were obtained using the Publish or Perish (PoP) software on the Google Scholar database. The following publication trend expresses in the form of graphic visualization, which is analyzed using VOSviewer software. Overall, articles with the keyword virtual laboratory published in the late 2020-2021 period focus on its relationship with Covid 19 and evaluation. This focus of research shows that during the past year, the focus of research is how to evaluate learning through virtual laboratories.

1. Introduction
Students' experience in carrying out experiments in the laboratory is a factor in engineering and science education [1]. Science learning accompanied by the implementation of experiments in the laboratory is expected to be able to provide experience for students in the form of experience in proving scientific concepts that have been studied or discovering new ideas through experimental activities, as well as being able to remember and understand science concepts better [2]. In addition, laboratory activities can teach performance skills to find an idea and communicate it [3]. Students can carry out laboratory activities face-to-face in the laboratory or virtual laboratories.

An experimental activity carried out using computer software through experimental simulations that resemble practical exercises directly is referred to as a virtual laboratory [4][5][6]. There have been many studies related to the need for virtual laboratories in science education. A literature study conducted in 2010 showed that a virtual laboratory based on a constructivist learning approach at the high school and university level showed several advantages of a virtual laboratory [7]. The study results showed that students better reported experimental results through virtual laboratories, requiring shorter practical times than face-to-face laboratories. Students became more focused on carrying out experiments, all students could participate in experiments, and the implementation of experiments became more efficient. Interesting because students can repeat the investigation if there is an error in data collection without coming to the laboratory [7].

Along with the development of science and technology, especially information and communication technology, the description of the integration of the implementation of virtual laboratories continues to
grow. There is a need for a new set of systems to build a modern virtual laboratory system that can create exciting experiences through a virtual laboratory environment [8]. Before the COVID-19 pandemic at the end of 2019, the focus of research related to virtual laboratories was the need for virtual laboratories to complement conducting experiments in laboratories. However, this opinion shifted after the COVID-19 pandemic occurred.

Currently, schools are struggling to change the education system from face-to-face learning to distance learning. The focus of implementing science learning during the COVID-19 pandemic is how to develop appropriate science teaching strategies and techniques related to the implementation of distance learning [9]. However, the performance of a virtual laboratory has not been able to provide the same experience as a face-to-face laboratory [2]. With the passage of time and the emergence of several research publications related to virtual laboratories, concerns about the implementation of virtual laboratories began to decrease. This concern is accompanied by the emergence of recognition that social and interpersonal interactions can also be developed and occur through distance learning [10]. During the COVID-19 pandemic, several research results reported solutions related to the implementation of science learning, especially in the performance of experimental activities. One way to find out the trend of these publications is through bibliometric analysis.

Bibliometric analysis is a quantitative study of bibliographic materials that can provide an overview of studies grouped by articles, authors, and journals [11]. This study discusses bibliometric analysis with the keywords virtual laboratory in the Google Scholar database. The purpose of this study is to determine the trend of publications related to virtual laboratories during the covid 19 pandemics, seen from the keywords, and the number of citations in articles published during the 2020-2021 timeframe.

2. Method
This research is a literature study to determine the trend of publications related to virtual laboratories during the covid 19 pandemic. This research was carried out in 4 stages, namely: (1) selection of the research criteria, (2) selection of a period and type of documents, (3) bibliometric analysis, (4) co-occurrences analysis.

2.1. Selection of the research criteria
The scientific articles analyzed came from the publication of the Google Scholar database with the keyword "virtual laboratory." Article search is carried out using the Publish or Perish (PoP) software.

2.2. Selection of a period and type documents
The covid 19 pandemics have been going on since 2019, so scientific articles related to the analyzed virtual laboratory keywords were selected for the 2020-2021 period. The publication in 2021 is limited to articles published until August 2021.

2.3. Bibliometric analysis
The bibliometric analysis stage is the stage to analyze scientific articles related to virtual laboratories, including the number of publications related to these keywords in the 2020-2021 period, the most relevant publications related to virtual laboratories during the covid 19 pandemic, and analysis of publication trends related to virtual laboratories during the covid 19 pandemic.

2.4. Co-occurrences analysis
The last step in this research is to visualize the data obtained using VOSviewer software. The data visualization in question is a visualization of the relationship between publication keywords, publication trends related to virtual laboratories during 2020-2021, and the density of relationships between keywords and virtual laboratories. Data analysis was carried out by paying attention to the virtual laboratory keywords in the titles, keywords, and contents of publications related to virtual laboratories for the 2020-2021 period.
3. Result and Discussion
The research results obtained are expected to provide an overview of publication trends related to virtual laboratory research during the covid-19 pandemics. Table 1 shows articles obtained using Publish and Pheris (PoP) software based on the Google Scholar database.

Table 1. PoP metric data output

| Metric Data          | Output                        |
|----------------------|-------------------------------|
| Keyword              | “virtual laboratory”          |
| Year of publication  | 2020-2021                     |
| Number of articles   | 500                           |
| Citation             | 1009                          |
| Citation/year        | 1009                          |
| Citation/article     | 2.02                          |
| Author/article       | 2.82                          |
| h_index              | 14                            |
| g_index              | 24                            |
| hl_normal            | 9                             |
| hl_yearly            | 9                             |

Based on the data obtained through the PoP software, the ten articles most relevant to the research objectives were then selected, presented in table 2. The relevance of these articles was determined based on the existence of a virtual laboratory relationship with covid 19. Table 2 shows that the pieces with the highest level of relevance have been cited nine times, although the article was published in 2021. The number of citations shows that the implementation of virtual experiments through virtual laboratories is essential as a reference for similar research.

Table 2. Top 10 articles with the highest relevance by PoP

| No | Year of Publication | Author                          | Title                                                                 | Journal                          | Citation | Publisher       |
|----|---------------------|--------------------------------|-----------------------------------------------------------------------|----------------------------------|----------|-----------------|
| 1  | 2021                | Kapilan, N Vidhya, P Gao, X Z  | Virtual laboratory: A boon to the mechanical engineering education during a covid-19 pandemic[13] | Higher Education for the Future   | 9        | Sage Journals   |
| 2  | 2021                | Radhamani, R Kumar, D Nizar, N Achuthan, K | What virtual laboratory usage tells us about laboratory skill education pre-and post-COVID-19: Focus on use, behavior, intention, and adoption[14] | Education and Information Technologies | 1        | Springer Link   |
| 3  | 2020                | M. Garcia-Velal, J.L. Zambrano, D.A. Falquez, W. Pincay-Musso, K.B. Duque, N.V. Zumba, M.B. Barcia, J.I. Méndez, P.E. Valverde, | Management of virtual laboratory experiments in the geosciences field in the time of COVID-19 pandemic[15] | Proceedings of ICERI2020 Conference | 2        | Researchgate.net |
| No. | Year | Authors | Title                                                                 | Journal                                      | DOI |
|-----|------|---------|----------------------------------------------------------------------|----------------------------------------------|-----|
| 4   | 2021 | Yap, W H Teoh, M L Tang, Y Q Goh, B H | Exploring the use of virtual laboratory simulations before, during, and post COVID-19 recovery phase: An Animal Biotechnology case study[16] | Biochemistry and Molecular Biology Education |     |
| 5   | 2020 | Sherrer, S M | A virtual laboratory module exploring photosynthesis during COVID-19[17] | Biochemistry and Molecular Biology Education |     |
| 6   | 2020 | Vasiliadou, R | Virtual laboratories during coronavirus (COVID-19) pandemic[18] | Biochemistry and Molecular Biology Education | 24  |
| 7   | 2021 | Bunyamin E Siregar E Kusumawardani D | Analysis of Development Needs Virtual Laboratory for Learning Vocational School Practices in the Pandemic Time Covid-19[19] | Journal of Education Research and Evaluation |     |
| 8   | 2021 | Mafudi, I Handhika, J | Virtual Laboratory: Using Electronic Workbench as Alternative Learning Physics in Covid-19 Mass Pandemic[20] | Impulse: Journal of Research and Innovation in Physics Education |     |
| 9   | 2020 | Lohrasbi, M | Chemistry Training with the help of Virtual Laboratory in the Corona Era[21] | Research in Chemistry Education |     |
| 10  | 2021 | Tamura, N Taira, H Umemura, K | Challenges of a “Virtual” Biophysics Laboratory during the “Stay home” period caused by COVID-19[22] | Journal of Physics: Conference Series |     |

VOSviewer is a computer program that can create, visualize, and explore data mapping in bibliometric science and can be used to analyze large amounts of data [23]. Data visualization using VOSviewer in this study are network visualization, overlay visualization, and density visualization.
Figure 1. The Visualization of the network in google scholar

Figure 1 shows a visualization of the relationship between keywords in the publications contained in the Google Scholar database. The color difference in Figure 1 shows that there are five keyword clusters, namely blue, yellow, green, purple, and red color clusters. Keywords in closely related publications will usually be located close to each other and are indicated by the same color line. Based on Figure 1, the virtual laboratory keywords are shown in red and are closely related to publications related to attitude, chemistry, computers, and distance learning.

Figure 2. The visualization of the google scholar databases overlay
Figure 2 shows the level of novelty of the publication keywords through the color change from purple to yellow. Table 2 keywords for the latest publications are covid, evaluation, inquiry, virtual laboratory medium, and virtual laboratory application. However, when viewed from the relationship with virtual laboratories, the keywords covid and evaluation of publications have the closest relationship.

Figure 3 shows the density of relationships between keywords covered in the same region. The bold color indicates a very close relationship between these keywords. The information obtained from Figure 3 is that the keyword attitude has the most intimate relationship with the virtual laboratory. This result shows that the discussion regarding the implementation of virtual laboratories during the COVID-19 pandemic did not dampen the teacher's intention to provide learning that does not just convey material but still pays attention to student attitudes.

The information that can be summarized based on the visualization of images 1, 2, and 3 is the latest trend of publications related to virtual laboratories during the covid 19 pandemic, related to the keywords of covid publications and evaluation. However, Figure 3 shows that many publications still focus on the relationship between virtual laboratories and attitude.

Evaluation is a procedure used to determine whether the subject (i.e., students) meets the predetermined criteria [23]. Discussions on evaluation in the implementation of virtual laboratories become more dominant during the performance of distance learning. The initial concept of implementing a virtual laboratory in science learning is as a solution to science problems. The problem is related to the difficulty of teaching abstract science concepts, which causes students to be less interested in learning science. The idea of virtual laboratories has now shifted to including didactic aspects in virtual laboratories and how to evaluate them [8].

The novelty of this research lies in the success of providing an overview of publication trends related to virtual laboratories during the COVID-19 pandemic using the Google Scholar database. However, the drawback of this study is that it has not revealed the publication trend in terms of the author and the author's country of origin, so that it has not been able to provide an overview of the publication trend related to virtual laboratories during the COVID-19 pandemic as a whole.
4. Conclusion

Overall, articles with the keyword virtual laboratory published in the late 2020-2021 period focus on its relationship with Covid 19 and evaluation. The results of this study can be used as a reference to carry out further research related to the development of learning tools in virtual laboratories and the implementation of these learning tools. During the past year, the focus of research has been on evaluating learning through virtual laboratories. Some suggestions related to this research are: (1) the need for an analysis of the relationship between the author and the country of origin, (2) changing the database for collecting publication articles other than Google Scholar, and (3) the need for research on how to evaluate knowledge, attitudes, and skills in the implementation of virtual laboratories.

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