# THE UTILIZATION OF VIRTUAL LABORATORY IN LEARNING: A META-ANALYSIS

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| Article Info | ABSTRACT |
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| | This study aimed to analyze the use of technology in the form of virtual laboratories in learning, including: (1) problems that cause the use of virtual laboratories in learning, (2) variables that are influenced by the use of virtual laboratories in learning, and (3) Scientific fields that utilize virtual laboratories in learning. The research method used was a meta-analysis with a sample of 30 international journal articles. Data collection was done by collecting similar scientific articles related to virtual laboratories and then analyzing them. The results of this meta-analysis study indicate that the main problem that causes the use of virtual laboratories in learning is the low understanding of students' concepts of learning topics. Furthermore, the variable most affected by the use of virtual laboratories is student achievement. Finally, the scientific field that most often utilizes virtual laboratories in learning is Physics. |

# PEMANFAATAN *VIRTUAL LABORATORY* DALAM PEMBELAJARAN: META-ANALISIS

| Kata Kunci: | ABSTRAK |
|---|---|
| | Penelitian ini bertujuan untuk menganalisis pemanfaatan teknologi berupa laboratorium virtual dalam pembelajaran yang mencakup: (1) permasalahan yang menyebabkan pemanfaatan laboratorium virtual dalam pembelajaran, (2) Variabel yang dipengaruhi oleh pemanfaatan laboratorium virtual dalam pembelajaran, dan (3) bidang keilmuan apa saja yang memanfaatkan laboratorium virtual dalam pembelajaran. Metode penelitian ini adalah meta-analisis dengan sampel sebanyak 30 artikel pada jurnal internasional. Pengumpulan data dilakukan dengan mengumpulkan artikel ilmiah yang sejenis terkait dengan laboratorium virtual dan kemudian menganalisisnya. Hasil penelitian meta-analisis ini menunjukkan bahwa permasalahan utama yang paling banyak menyebabkan pemanfaatan laboratorium virtual dalam pembelajaran adalah rendahnya pemahaman konsep siswa terhadap materi yang dipelajari. Selanjutnya mengenai variabel yang banyak terpengaruh dengan pemanfaatan laboratorium virtual adalah prestasi belajar siswa. Terakhir terkait bidang keilmuan yang paling sering memanfaatkan laboratorium virtual dalam pembelajaran adalah bidang Fisika. |

## 1. INTRODUCTION

School laboratories are very important because they have various functions, including: 1) a place to find solutions to learning problems, 2) a good place for students to do experiments, exercises, demonstrations or other methods, 3) a place where students prove the facts, principles, and concepts of a theory, 4) provide opportunities for students to work with certain tools and materials, cooperate with friends, be motivated to reveal the truth of a theory and find satisfaction with the results achieved, 6) create good habits and useful skills [1]. Based on the type, laboratory is divided into real laboratory and virtual laboratory. Virtual Laboratory is a laboratory that uses simulations to display experimental processes. The principle of virtual learning is basically a learning process that is carried out by utilizing technology[2].

The use of virtual laboratories generally occurs because not all practicum can be carried out through experimental activities in real laboratories. Theories or concepts that are abstract and difficult to explain using equipment in real laboratories, but still require real observations, are simulated using a system. A virtual laboratory is a system that can be used to support a conventional practicum system, so that the use of this virtual laboratory can provide opportunities for students to do practicum via computer, and experiments are possible to do anywhere. The use of a virtual laboratory can overcome several problems related to inadequate laboratory equipment and make a positive contribution in order to achieve learning purposes, especially for abstract concepts[3].

PhET is an application that provides virtual practicum that is most often used in learning. Based on the results of previous research, it is known that PhET media simulation can help students to understand concepts, receive feedback, and provide an interactive, constructivist approach, and train students to think critically and creatively [4].

The advantages of using a virtual laboratory according to researchers from Labshare are: (1) Increase access to laboratories, (2) Reduce laboratory management and maintenance costs by up to 50%, (3) Improve the quality of learning to support better learning, (4) Encourage the exchange of knowledge, expertise and experience, (5) Reducing laboratory equipment supplier costs [5].

With this virtual laboratory, it helps teachers to keep abreast of technological developments, especially to streamline learning during (and after) the Covid-19 pandemic. Covid-19 pandemic demands creativity and innovation from teachers to find ways to deliver effective learning topics. It cannot be denied that Covid-19 pandemic requires students to maximize 21st century skills, including: communicative, collaborative, critical thinking, creative and innovative[6].

Previously, several studies have conducted meta-analysis of various learning methods in the education system, such as meta-analysis of learning systems in schools and universities in improving critical thinking [7], meta-analysis of the effectiveness of 7E learning in education [8], and many more [9], [10], but all of these studies examined learning systems or methods. Although various meta-analyzes have been carried out, no one has analyzed the reasons and the effectiveness of using virtual laboratories in learning. This research is here to fill in these gaps. In this literature study, an analysis was carried out on previous studies related to the use of virtual laboratories in learning. Includes reasons for using virtual laboratories in learning, variables that are influenced by the use of virtual laboratories in learning, and scientific fields that are suitable for using virtual laboratories.

## 2. METHOD

This study used the meta-analysis method, which is a statistical technique that combines the results of previous studies with similar problems, so that a quantitative and systematic data mix is obtained, with the aim of drawing a conclusion [11]. In other words, meta-analysis is a technique aimed at re-analyzing research results that are processed statistically based on primary data collection[12].

In this meta-analysis research, data collection was carried out by collecting research results from scientific articles related to virtual laboratories and their use in learning. The number of articles sampled is 30 scientific articles from international journals. The distribution of 30 subject articles in this study can be seen in Table 1 below.

**Table 1.** Problems that Cause the Use of Virtual Laboratories in Learning

| No | Problem | Frequency | Variables that are affected | Scientific Field |
|----|---------|-----------|----------------------------|------------------|
| 1 | Facilities and equipment | 3 | | |
| 2 | Time | 3 | | |
| 3 | Low understanding of concepts | 6 | | |
| 4 | Cost | 3 | | |
| 5 | Not independent and not confident | 6 | | |
| 6 | The need for learning innovation | 2 | | |
| 7 | Hazardous material | 2 | | |
| 8 | Abstract concept | 5 | | |
| 9 | Achievement | | 8 | |
| 10 | Concept Understanding | | 6 | |
| 11 | Science Process Skills | | 4 | |
| 12 | Scientific Attitude | | 4 | |
| 13 | Science Literacy | | 3 | |
| 14 | Critical Thinking Skills | | 2 | |
| 15 | Skills | | 2 | |
| 16 | Learning outcomes | | 2 | |
| 17 | Basic Clinical Skills | | 1 | |
| 18 | Communication Skills | | 1 | |
| 19 | Laboratory Experience | | 1 | |
| 20 | Confidence | | 1 | |
| 21 | Thinking Skills | | 1 | |
| 22 | Creativity | | 1 | |
| 23 | Problem Solving Skills | | 1 | |
| 24 | Learning Experience | | 1 | |
| 25 | Learning activity | | 1 | |
| 26 | Learning Effectiveness | | 1 | |
| 27 | Physics | | | 15 |
| 28 | Chemistry | | | 5 |
| 29 | Biology | | | 4 |
| 30 | Natural Science | | | 4 |
| 31 | Electrical Engineering | | | 2 |
| | TOTAL | 30 | 30 | 30 |

Data were collected by identifying the observed variables through coding methods. The coding is carried out in accordance with the research variables: "problems that cause the use of virtual laboratories in learning, variables that are influenced by the use of virtual laboratories in learning, and scientific fields that use virtual laboratories in learning". Furthermore, the collected data were analyzed using descriptive statistical techniques.

The data tabulation stage is to identify the research variables and classify them according to their type. Next, identify the mean and standard deviation of the experimental and control group data and calculate the effect size using the Glass formula.

$$\Delta = \frac{\bar{x} \, experiment - \bar{x} \, control}{SD \, Control} \qquad (1)$$

with:
*Effect size* $\leq 0{,}15$ (negligible effect)
$0{,}15 <$ *effect size* $\leq 0{,}40$ (small effect)
$0{,}40 <$ *effect size* $\leq 0{,}75$ (moderate effect)
$0{,}75 <$ *effect size* $\leq 1{,}10$ (high effect)
$1{,}10 <$ *effect size* $\leq 1{,}45$ (very high effect)
$1{,}45 <$ *effect size* high influence

## 3. RESULTS AND DISCUSSION

The results of this study indicate that problems in learning that require the use of virtual laboratories based on the 30 journal articles that have been analyzed can be seen in Table 2 below.

**Table 2.** Problems that Cause the Use of Virtual Laboratories in Learning.

| No | Problem | Total | Percentage |
|---|---|---|---|
| 1 | Facilities and equipment | 3 | 10 % |
| 2 | Time | 3 | 10 % |
| 3 | Low understanding of concepts | 6 | 20 % |
| 4 | Cost | 3 | 10% |
| 5 | Not independent and not confident | 6 | 20 % |
| 6 | The need for learning innovation | 2 | 6,67 % |
| 7 | Hazardous material | 2 | 6,67 % |
| 8 | Abstract concept | 5 | 16,67 % |

Based on Table 2 above, there are 2 main problems that cause the use of virtual laboratories in learning, students' low understanding of concepts on the learning topics, which were mentioned by 6 articles ([13], [14], [15], [16], [17], [3] and students who were not independent and not confident during learning in the real laboratory, stated by 6 articles ([13], [14], [15], [16], [18], [19]). The use of virtual laboratories made learning more interesting and trained students' independent learning through tasks that must be done independently. Thus, the use of virtual laboratories could improve students' understanding of concepts and independence in learning physics [16]. Virtual laboratories can help students to improve their scientific literacy skills, because the media presented is in accordance with concepts, pictures, and questions related to scientific literacy skills, even simulations of laboratory work are made as real as possible according to the concepts [13].

Besides, abstract concepts that cannot be practiced in real laboratories (due to limitations of practicum tools) were also a common problem which was the reason for using virtual laboratories (stated by 16.67% of the 30 articles analyzed). In line with Damayanti's research results which state that virtual laboratory media can improve students' science process skills [20]. Furthermore, other problems that cause the use of virtual laboratories are time efficiency factors, costs (practicum with real laboratories requires high costs), risk (some lab work is dangerous to do in real laboratories), and the need for innovation in learning. Virtual Laboratory can be defined as a series of computer programs that can visualize abstract phenomena or complex experiments to be carried out

in a real laboratory, so that it can increase learning activities to develop problem solving skills [21].

Several research studies have shown that the use of virtual laboratories was more effective in increasing students' conceptual understanding than learning in real laboratories. The use of virtual laboratories in the learning process made the learning process more effective, efficient, and able to improve student learning achievement [19]. In line with that, the results of research conducted by Gunawan et al. showed that learning using a virtual laboratory affected the increase in students' mastery of concepts [22].

The aspects related to virtual laboratory are dependent variables that can be influenced or increased through the use of virtual laboratories. These aspects were found based on the analysis of 30 journal articles. The results of the analysis can be seen in Table 3 below.

**Table 3.** Variables that are Influenced by the Use of Virtual Laboratories in Learning.

| No | Variable | Total | Percentage |
|----|----------|-------|------------|
| 1 | Achievement | 8 | 26,67% |
| 2 | Concept Understanding | 6 | 20 % |
| 3 | Science Process Skills | 4 | 13,33% |
| 4 | Scientific Attitude | 4 | 13,33% |
| 5 | Science Literacy | 3 | 10 % |
| 6 | Critical Thinking Skills | 2 | 6,67% |
| 7 | Skills | 2 | 6,67% |
| 8 | Learning outcomes | 2 | 6,67% |
| 9 | Basic Clinical Skills | 1 | 3,33% |
| 10 | Communication Skills | 1 | 3,33% |
| 11 | Laboratory Experience | 1 | 3,33% |
| 12 | Confidence | 1 | 3,33% |
| 13 | Thinking Skills | 1 | 3,33% |
| 14 | Creativity | 1 | 3,33% |
| 15 | Problem Solving Skills | 1 | 3,33% |
| 16 | Learning Experience | 1 | 3,33% |
| 17 | Learning activity | 1 | 3,33% |
| 18 | Learning Effectiveness | 1 | 3,33% |

Based on Table 3 above, it can be seen that the use of virtual laboratories has the most influence on learning achievement, mentioned by 8 articles ([23], [24], [25], [18], [19], [26],[27], [28]) out of 30 articles found (26.67%). Learning achievement in the *Kamus Besar Bahasa Indonesia* (Indonesian Dictionary) is the mastery of knowledge of the skills developed by subjects, usually shown by tests or scores given by the teacher [29]. Learning achievement is the result obtained through practice and experience supported by awareness [30]. Learning achievement is said to be perfect if it fulfills three aspects: cognitive, affective and psychomotor. Therefore, learning achievement can be said to be the result of changes in the learning process. Different methods used by teachers can cause differences in the learning process which will also affect student achievement. Simulation and experimental methods in virtual laboratories can foster conceptual understanding in students.

Based on the data that has been collected, there were 6 scientific articles ([13], [14], [15], [16], [17], [3]) of the 30 articles analyzed showed that the use of virtual laboratories had a positive effect on students' conceptual understanding. This is revealed by the results of previous research which concluded that the understanding of concepts and student achievement in learning physics can be improved through the use of virtual laboratories [26]. After implementing the PDEODE learning model assisted by the PhET simulation,

students gave a positive response and stated that learning about fluid material was fun, so it could reduce student misconceptions in learning physics [4].

The results of research conducted by Osman and Kaur showed that the learning outcomes of the experimental group using virtual media were higher than the control group who did not use virtual media [31]. This shows that learning using virtual laboratory media can improve students' conceptual understanding.

Furthermore, scientific fields that utilize virtual laboratories in learning based on 30 articles that have been analyzed can be seen in Table 4 below.

**Table 3.** The Scientific Field that makes the most Use of the Virtual Laboratory in Learning

| No | Scientific Field | Total | Percentage |
|----|------------------|-------|------------|
| 1 | Physics | 15 | 50% |
| 2 | Chemistry | 5 | 16,67% |
| 3 | Biology | 4 | 13,3% |
| 4 | Natural Science | 4 | 13,3% |
| 5 | Electrical Engineering | 2 | 6,67% |

Based on Table 4 above, it can be seen that virtual laboratories are widely used in learning Physics, which were found in 15 articles ([13], [32], [33], [16], [23], [34], [35], [22], [3], [26], [36], [4], [37], [38], [28]) out of 30 articles (50%). Physics is a branch of science that is acquired through the scientific method to reveal the nature of matter and its interactions with other objects in the universe. Physics is a science that is produced through observations and experiments carried out by experts who developed laws, principles, concepts, rules in the form of mathematical equations or statements.

Learning topics related to theoretical concepts in physics require simulations to support student understanding. The problem that often happen in learning Physics is the lack of understanding of students' concepts of learning topics, resulting in students not being independent and not confident in doing practicum. In addition, the concept of physics is abstract and difficult to prove in a real way (due to complexity), resulting in misconceptions among students. Therefore, it is more effective to use virtual laboratories to support conceptual understanding of physics material (because students can easily access simulated proof of theory through virtual laboratories). This is in line with the results of previous research which stated that the use of virtual laboratories in physics learning has a positive impact on students' conceptual understanding [26].

Previous studies have conducted meta-analysis of various learning methods in the education system, such as meta-analysis of learning systems in schools and universities in improving critical thinking [7], meta-analysis of the effectiveness of 7E learning in education [8]. However, no one has analyzed the reasons and the effectiveness of using virtual laboratories in learning. In this literature study, an analysis was carried out on previous studies related to the use of virtual laboratories in learning. Includes reasons for using virtual laboratories in learning, variables that are influenced by the use of virtual laboratories in learning, and scientific fields that are suitable for using virtual laboratories

## 4.    CONCLUSION

From the results of the meta-analysis, it can be concluded that virtual laboratories, as part of learning media, can be used in learning to overcome students' conceptual understanding problems and low self-confidence of students when carrying out practical learning in real laboratories. The most influenced or related variable to the use of virtual laboratories is student achievement. And the use of virtual laboratories in learning is mostly used in learning Physics, then Chemistry. The principle of virtual learning is the learning

process carried out by utilizing technology. The use of virtual laboratories as a medium has a better effect on learning problems. So it is important for teachers to follow technological developments. This is closely related to the role of a teacher to pay attention to their competence in teaching learning topics using virtual laboratories. Learning activities in virtual laboratories which are a product of technological advancement innovation can be an alternative solution to overcome obstacles in the learning process during the Covid-19 pandemic.

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