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Meta-Analysis: The Effect of Using a Virtual Laboratory to Improve Students' Understanding of Physics Concepts

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ABSTRACT

This study aims to: (1) analyze the model/strategy/method of using virtual laboratories in learning physics, (2) analyze the effect of virtual laboratories in learning physics on increasing students' understanding of concepts. The method used in this research is meta-analysis. The collected articles totaled 20 articles published in the last 10 years in national and international journals. Data analysis was performed using predetermined instruments and effect size formulas. The results of the research are learning models/learning strategies/learning methods for using virtual laboratories in physics learning to improve students' understanding of concepts, there are 6 learning models, and 2 learning approaches. The inquiry learning model is the most widely used. static fluid material has a good effect on students' understanding of concepts. with an average effect size value of 1.81 with a high influence category.

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INTRODUCTION

Technological and information advances in Indonesia are currently experiencing very rapid increases. As technology and information improve, education experts have started to use computer-based learning media, for example interactive videos (*e-books*), flash macros, and the use of virtual laboratories (Sumargo, 2014). Using appropriate learning media will make learning more interesting, make students active and increase interest in wanting to learn. The existence of technology applications implemented in schools hopes that students will be more motivated to study seriously.

Education is needed to develop students' abilities. Juhendi (2015) said that in the world of education it is necessary to connect theory with practice. The concepts or theories that have been presented will be studied in practice. What is found in practical experience is sought for its basis in theory. Where theory and practice alternately and gradually examine each other for truth. These practical learning activities can be carried out in the school laboratory.

Physics learning emphasizes providing direct experience to develop student competence. Learning is directed at finding out and doing so, helping students to gain a deeper experience of the natural surroundings. Understanding physics material is not only done through teacher explanations that are too monotonous. However, it is strengthened through experiments carried out so that the concepts taught can be understood by students. Laboratory practicum is one way to achieve this goal. Physics practicum provides a natural opportunity for students to learn to carry out an experiment and analyze the data obtained in accordance with the objectives of the experiment being carried out (Juniantari, 2017).

A school laboratory is a complete learning facility that should not be neglected in learning. A laboratory is an infrastructure that must be provided by school administrators to support teaching and learning activities in accordance with the Regulation of the Minister of National Education of the Republic of Indonesia Number 24 of 2007 concerning standards for facilities and infrastructure which stipulates that a SMA/MA must have facilities and infrastructure that must be owned by school institutions. the other is the school physics laboratory.

The importance of laboratories as educational facilities to achieve competency according to the curriculum means that educational facilities in schools need to be managed as well as possible so that the use of laboratories is more effective. According to Setyaningrum et al (2013), the effectiveness of practicum implementation is influenced by many factors, including laboratory management, laboratory facilities, availability of tools and materials and students' attitudes towards practicum activities. The time allocation given by the teacher will also influence the effectiveness of practical activities in the laboratory.

Based on the results of observations by researchers at one of the state high schools in Gunung Talang sub-district, physics learning in schools predominantly treats physics as a collection of knowledge. This is related to the learning process which is still teacher-centered. Students only get informational concepts conveyed by the teacher in class. Learning that fully conveys material without directly involving students in learning, causes students to be less interested in learning, resulting in reduced motivation and activity during the learning process. Practicums in schools still have many problems. The obstacles experienced include limited laboratory facilities, as well as difficulty carrying out practical work on abstract physics concepts. In abstract physics concepts, there are

The difficulty in displaying physical processes directly through real laboratory activities causes students' level of mastery of physics concepts and creative thinking abilities to be low. This then has implications for students' low mastery of physics concepts.

One solution to the limited laboratory facilities and infrastructure is to carry out virtual practicums. Development of a physics virtual laboratory to help students understand physics concepts and at the same time improve students' and teachers' abilities in the field of ICT. A virtual laboratory is an interactive science situation with the help of computer applications in the form of science experiment simulations. Virtual laboratories can be used to assist the learning process in order to improve students' understanding of the material, and are also suitable for anticipating unpreparedness in real laboratories (Sutrisno, 2011). Soni and Katkar (2014) say that a virtual laboratory is an interactive experience where students observe and manipulate the resulting system objects, data, or phenomena in order to meet learning objectives.

One of the virtual laboratories that will be used in this research is *Physics Education Technology* (PhET) *simulation*. The choice of using the PhET virtual laboratory is because this simulation is designed to make it easier for teachers to guide students to develop their

mastery of physics concepts. The PhET simulation used consists of objects that are invisible to the eye, for example small molecules, electrons, electric fields and photons (Sunni, 2014).

In order to be able to identify more specifically the influence of the use of virtual laboratories on students' understanding of physics concepts, it is necessary to conduct a study in the form of document analysis of research results that have been published from various credible scientific articles. This analysis is then called meta-analysis. Meta analysis is research that uses existing studies that have been used by researchers which are carried out systematically and quantitatively to obtain accurate conclusions (Retnawati, 2018).

Based on the explanation above, researchers are interested in conducting research with the title Meta Analysis: The Effect of Using a Virtual Laboratory to Improve Students' Understanding of Physics Concepts. The aim of the research is to determine the effect of using a virtual laboratory from several similar studies on students' mastery of concepts..

METHODS

The research method used is descriptive research using a meta-analysis information gathering approach. Sampling technique viz *purposive sampling*. *Purposive sampling* is a sampling technique using certain criteria (Sugiono, 2008). The sample criteria are set namely (1) the articles used are articles that have been published for the last 10 years (2012-2022), (2) carried out in high school education units of the equivalent, (3) the journal uses the experimental method, (4) all journal information is complete to determine needs *effect size* found in research journals.

Meta-analysis is a form of research whose data sources are obtained from data from existing studies (secondary data) (Retnawati et al., 2018). In this study, researchers used several samples of previous research within the last 10 years about the use of virtual laboratories in physics learning to improve students' understanding of concepts. Based on many studies that are similar to the theme of using virtual laboratories in learning physics in increasing students' understanding of concepts, there is a slight difference at each research results, it is necessary to organize the data by digging up more information from the research that has been done.

Data collection begins with collecting a number of research results that have been published from various sources. The results of research that has been collected next classified based on learning materials, and learning models / learning methods / learning strategies used in learning physics, as well as record statistical data that will be used to calculate *effect size* each research result.

The data analysis technique uses group contrast analysis. Calculating the effect size of each research article can be determined using various formulas, as follows

$$ES = \frac{E_{posttest} - X_{pretest}}{SD_{pretest}} \quad (1)$$

Determining the effect size using the t-test, calculated using the following formula:

$$ES = \sqrt[t]{\frac{1}{n_E} + \frac{1}{n_C}} \quad (2)$$

(Becker & Park, 2011)

Based on interpretation effect size according to Dincer (2015) criteria effect size: The same small effect size of 0.15 is negligible, small effect size equals 0.40 large from 0.15 categorized low, small effect size equals 0.75 large from 0.40 categorized moderate, small effect size equals 1.10 large from 0.75 categorized high, small effect size equals 1.45 large from 1.10 categorized very high, and large effect size of 1.45 categorized high influence.

RESULTS AND DISCUSSION

Results

This research was conducted to determine the effect of using a virtual laboratory to improve students' understanding of physics concepts. The research results were reviewed from 20 articles that had been selected based on predetermined criteria. The following is an appendix of studies that apply the use of virtual laboratories to improve students' understanding of physics concepts.

Table 1. Research on the Use of Virtual Laboratories to Improve Students' Understanding of Physics Concepts

Code	Year	Researcher	Name Journal
A6	2020	Rada Fatikasari, Benyamin Matius, M. Junus	Jurnal Literasi Pendidikan Fisika
A7	2015	Yuniar Ekawati, Abdul Haris, Hj. Bunga Dara Amin	Jurnal Pendidikan Fisika
A8	2019	Yeni Megalina, Sari Paganda Sinambela	Jurnal Inovasi Pembelajaran Fisika
A9	2021	Mahira Ulfah Abdi, Mustafa, Andi Ulfa Tenri Pada	Jurnal IPA dan Pembelajaran IPA
A10	2016	Mukti Herdiana, Eko Setyadi Kurniawan, Ashari	Radiasi: Jurnal Berkala Pendidikan Fisika
A11	2020	Egidius Dewa, Maria Ursula Jawa Muklin, Oktavina Pandango	Jurnal Riset Teknologi dan Inovasi Pendidikan (JARTIKA)
A12	2018	Khofifatul Rasyidah, Supeno, Maryani	Jurnal Pembelajaran Fisika
A13	2022	Siti Magfirah, Susanna, Saminan	Jurnal Pendidikan Sains dan Humaniora
A14	2020	Adytia Permana Putra, Chaerul Rochman, Winda Setya	Journal of Teaching and Learning Physics
A15	2021	Aldi Tupalessy, Cicylia Triratna Kereh, Sarlota Singerin	Science Map journal
A16	2015	Hermansyah, Gunawan, Lovy Herayanti	Jurnal Pendidikan Fisika dan Teknologi
A17	2016	Tantawi Jauhari, Hikmawati, Wahyudi	Jurnal Pendidikan Fisika dan Teknologi
A18	2016	Mahesti Kusdiastuti, Ahmad Harjono, Hairunnisyah Sahidu, Gunawan	Jurnal Pendidikan Fisika dan Teknologi
A19	2017	Hermansyah, Gunawan, Ahmad Harjono	Jurnal Pendidikan Fisika dan Teknologi
A20	2020	Nurbaiti, Kosim, Muhammad Taufik	Jurnal Pendidikan Fisika dan Teknologi

A21	2016	I Nyoman Sugiana, Ahmad Harjono, Hairunnisyah Sahidu, Gunawan	Jurnal Pendidikan Fisika dan Teknologi
A22	2020	Rozi Saputra, Susilawati dan Ni Nyoman Sri Putu Verawati	Jurnal Pijar Mipa
A23	2018	Halimatus Sakdiah, Petri Reni Sasmita	Jurnal Pendidikan Fisika
A24	2018	A.M. Miftah Farid, Andi Rafiqa Faradiyah, Aina Magfira, Asrianti Putri Lestari, Hidayat Tullah	Jurnal Nalar Pendidikan
A25	2020	Ega Prastika, Andika Purwanto, Nirwana	Jurnal kumparan fisika

Information is obtained from journals that are relevant to research and support for calculating the effect size of each article. The results obtained from the calculation of the effect size of the 20 articles.

Tabel 2. Learning Model/Learning Method/Learning Strategy/Learning Approach for the Use of Virtual Laboratories In Physics Learning

Article Code	Learning Models / Learning Methods / Learning Strategies / Learning Approaches for The Use of Virtual Laboratories in Physics Learning.	Effect Size
A6	Inquiry Learning Model	1.81
A12		0.05
A18		1.05
A19		1.26
A15	Discovery Learning Model	0.17
A24		
A8	Learning Model *Assurance*, *Relevance*, *Assessment*, *dan Satisfaction* (ARIAS)	0.52
A9	STEM (*Science*, *Technology*, *Engineering*, *and Mathematic*) Approach	0.98
A20	*predict-observe-explain* (POE) models	1.05
A21	Generatif Learning Model	0.04
A23	TGT Learning Model	0.61
A25	*Interactive conceptual instruction* (ICI) Approach	0.61

Based on the table above it is known that there are 6 learning models used in the virtual laboratory for physics learning and there are 2 learning approaches used. Based on the results of the study, it can be seen that the use of the virtual laboratory-assisted inquiry learning model for students' understanding of physics concepts is the most widely used.

Table 3. The Effect of The Use of Virtual Laboratories on Learning Physics on Increasing Students' Understanding of Concepts on Terms of Learning Materials

Subject Matter	Article Code	ES	ES Average	Category

Hooke's Low & Elasticity	A8 A9 A22 A23	0.52 0.96 1.10 0.62	0.80	High
Straight Motion	A7 A13	0.89 0.48	0.68	Moderate
Static Fluid	A6	1.81	1.81	High Influence
Effort & Energy	A12	0.05	0.05	Negligible
Newton's Low of Gravity	A24 A25	0.42 0,61	0.51	Moderate
Kinetic Theory of Gases	A14	0,16	0.16	Low
Simple Harmonic Motion	A15	0.18	0.18	Low
Vibrations & Waves	A16	0,56	0.56	Moderate
Heat	A17 A19	2.08 1.27	1.67	High Influence
Optical Tools	A18	1.05	1.05	High Influence
Momentum & Impulse	A20 A21	3.88 0.04	1.95	High Influence

Based on table 4, virtual laboratory-assisted physics learning on static fluid material has the highest average effect size value of 1.81.

Discussion

The first research result found in this study is the model learning / learning methods / learning strategies / learning approaches used in physics learning assisted by virtual laboratories. The total number of articles analyzed to answer the first research objective was 12 articles. Of the 12 learning model articles/learning methods/learning strategies, there are 6 learning models and 2 learning approaches used. The inquiry learning model is most widely used in virtual laboratory-assisted physics learning. This is in line with research by (Ni'mah, 2022) which explains that there is a significant difference between understanding concepts before and after using the structured inquiry model assisted by virtual laboratory PhET. Therefore, learning with structured inquiry learning assisted by PhET virtual labs can improve students' conceptual understanding. The same results were also obtained by (Narang et al, 2022) showing that virtual laboratory-based inquiry learning in increasing students' conceptual understanding had a very good effect in increasing students' conceptual understanding.

The inquiry learning model is an inquiry-based learning where students seek their own answers to the problems they face. According to Hafsyah (2012), inquiry learning is a series of learning activities for students to seek and investigate systematically, critically, logically and analytically, so that they can formulate their own findings. Inquiry contains higher level mental processes, for example formulating problems, designing experiments, conducting experiments, collecting and analyzing data, drawing conclusions, having objective attitudes, being honest, curious, being open and so on. Relevant to research (Asrizal, 2018) which explains that the application of learning models to improve student performance, especially in the knowledge aspect, science process skills integrating virtual laboratories provides satisfactory results in the cognitive aspects of students.

The second research result found in this study is the effect of using a virtual laboratory in physics learning on increasing students' understanding of concepts in terms of physics learning material, namely static fluid material has a value *effect size* the highest average is 1.81 with a very high influence category. This shows that in static fluid material students are more active in the learning process when using virtual laboratories. The results of this study are in line with the results of research conducted by Sugiana, et al (2016) which stated that static fluid material assisted by a PhET virtual laboratory has a significant influence on student learning outcomes.

The research that has been done has limitations in its implementation. First, there are still limited articles from national and international journals that discuss the effect of using virtual laboratories on physics learning to improve students' understanding of concepts. Second, the articles from the journals discussed in this study are limited, namely 15 articles in international indexed journals and 5 articles in national indexed journals. However, as a whole, the articles discussed have fulfilled the information needed for research on the effect of using virtual laboratories on learning physics to improve students' understanding of concepts.

CONCLUSION

Based on the research results obtained, it can be concluded that: learning models/learning strategies/learning methods for the use of virtual laboratories in physics learning to improve students' understanding of concepts there are 6 learning models, and 2 learning approaches. Each learning model serves to increase understanding of concepts according to the correct concept. Discovery learning and inquiry learning models are the most widely used learning models in the effect of using virtual laboratories on physics learning to improve students' understanding of concepts. This research resulted in a virtual laboratory-assisted physics learning that influences students' understanding of concepts.

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