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The Effectiveness of An Internet of Things (IoT)-based Virtual Science Laboratory on Nervous System Material in Science Course

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Abstract: This study aims to test the effectiveness of the Internet of Things (IoT)-based virtual science laboratory on nervous system material in science lectures. The research method used was an experiment with a pretest-posttest control group design, with the research subjects being randomly selected A3 and A4 class students in the PGRI Yogyakarta University PGSD study program who take science courses. Data was collected by giving a pre-test and post-test and measuring n-gain to determine the increase in concept understanding after using a virtual science laboratory. Data analysis was carried out using the t-test to test the significant difference between the pre-test and post-test results and the n-gain test to measure the effectiveness of virtual science laboratories in improving students' concept understanding. The results of this study indicated that the Internet of Things (IoT)-based virtual science laboratory on nervous system material effectively improves students' understanding of concepts. It can be seen from the average n-gain result of 0.72 in the experimental group, which shows a high increase in concept understanding. The t-test results showed a significant difference between the control group and the experimental group in terms of the effectiveness of the IoT-based virtual science laboratory on nervous system material.

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Introduction

The 21st century is a century that makes information and communication technology (ICT) an inseparable part of various aspects of life. Education is one aspect that has not been separated from using technology for a long time (Nisa, 2020). The characteristics of the 21st century are characterized by the increasingly intertwined world of science, so that developments among them become faster. In the context of utilizing information and communication technology in the world of education, it has been proven by the narrowing of the "space and time" factor, which has been the determining aspect of the speed and success of science (Raksa, 2020). However, in reality, the quality of education in Indonesia is still low. It is evident from the results of the Programme for International Student Assessment (PISA) Survey, which is a program initiated by the Organisation for Economic Co-operation and Development (OECD) to test the science, mathematics, and reading skills of 15-year-old students (Hewi & Shaleh, 2020). The results of the PISA survey show that Indonesia in science lessons is ranked 62 out of 70 countries with a score of 403 (Sutrisna, 2021).

Science is one of the main subjects in the education curriculum in Indonesia. Natural Sciences is always present in learning from elementary school to college level. Science is a science that studies events that occur in nature and can be proven true through experiments,

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practicum, observation, and active experimentation, which will eventually form creativity and awareness to form a scientific attitude, not an activity of memorizing and listening to explanations only (Indarwati et al, 2021; Sulthon, 2016). Science learning is important in education because it provides a deeper understanding of science concepts (Musi et al., 2022).

A science laboratory is a place where students can learn and experiment directly with science concepts, thus improving their understanding of the subject matter (Agustina, 2018). However, not all schools or universities have adequate and complete science laboratories to support learning. In addition, the COVID-19 pandemic has disrupted teaching and learning activities and forced many educational institutions to shift to distance learning. So, that raises concerns about the decline in the quality of knowledge that students have personally. Starting with the delivery of material that is not free, it is difficult to ask questions or consult with educators. In addition, the distance learning process organized by educators has yet to find the right format in many educational institutions, so its effectiveness is still often questioned.

In this case, a virtual science laboratory based on the Internet of Things (IoT) is one alternative to help students understand science concepts without coming to a physical laboratory. The IoT-based virtual science laboratory utilizes Internet of Things (IoT) technology that allows laboratory equipment to be connected to the Internet and can be accessed by students remotely through an online platform. Students can conduct experiments and observations through videos, images, and data from the virtual science laboratory.

Research on learning nervous system material using IOT-based virtual science laboratories is related to developing more innovative and effective learning methods to improve student understanding of the material taught. In addition, in the context of the Covid-19 pandemic, online learning or distance learning through internet media is the main choice to minimize the risk of spreading the virus (Aurelia, 2021; Prabandari & Sumarni, 2020). The utilization of Internet of Things (IoT) technology in virtual science laboratories is expected to be an effective alternative in distance learning (Handayani & Alfina, 2021; Prihatmoko, 2016). The IoT-based virtual science laboratory allows students to conduct experiments and observations with the help of technology to understand better the concepts taught (Pongoh & Budiman, 2022; Ramadiani et al., 2022).

Several recent studies have demonstrated the advantages of learning using IoT-based virtual science laboratories. Research (Leisenberg & Stepponat, 2019) developed an IoT demonstrator for distance learning purposes based on well-known specialized filter and classification algorithms and a practically available open cloud platform. In addition, research (Cîmpanu et al., 2019) consider the software and hardware deployment criteria of a virtual laboratory used for educational purposes. In 2020 there was also research (Benesha et al., 2020) which engineered a virtual lab for sports science using wearables and IoT, demonstrating the design and construction of experiments, along with prototyping software solutions that can all be operated remotely using a web-based client. The last research is (ABEKIRI et al., 2023) who developed a low-cost platform called LABERSIME that is installed in the cloud (LMS, IDE) and equipped with embedded systems to drive real laboratory equipment and conduct experiments qualitatively more efficiently compared to the face-to-face mode. In this context, research on learning using IoT-based virtual science laboratories, especially on nervous system material is very important to be developed and implemented.

In education, advances in new technologies, the rise of artificial intelligence, and IoT have transformed the learning environment from traditional-based learning to digital-based learning (Alhazmi et al., 2023). By utilizing IoT technology in virtual science laboratories,

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students are expected to understand the concepts taught and gain better practical experience more easily. In addition, learning using IoT-based virtual science laboratories can also help teachers develop more effective and efficient learning methods in the digital era. Science learning is important in education because it provides a deeper understanding of science concepts.

The utilization of this technology can provide a more interactive and enjoyable learning experience for students, while providing convenience and efficiency in learning. Many studies have been conducted to evaluate the effectiveness of IoT-based virtual science laboratories in science learning, including on nervous system material. One of the studies conducted (Ilyas et al., 2022) showed that the virtual laboratory based on science process skills integrated with zoom meetings effectively improved students' understanding of concepts. In addition, other research conducted by(Gaffar & Sugandi, 2019) stated that the virtual laboratory in the experimental class was more effective than the conventional practicum in the classroom so that the application of virtual practicum learning devices could improve the science process skills of high school students on invertebrate material.

It is supported by the survey results showing that most students feel more motivated and are more interested in learning through virtual science laboratories (Alatas & Fachrunisa, 2019; Bahtiar & Azmar, 2022; Bortnik et al., 2017; Hadi & Hermansyah, 2021; Raini, 2020; Rusliati & Retnowati, 2019; Susdarwati et al., 2021; Trisnawati & Yetri, 2019). However, it should be noted that the effectiveness of IoT-based virtual science labs in science learning is still a matter of debate among academics. Some studies show positive results, while others show less significant results. For example, research conducted by (Sarah, 2018) showed that there was no significant difference in investigation ability and chemistry learning achievement between students who participated in virtual lab-based practicum activities and students who participated in real lab-based practicum activities. Based on the research that has been done and has been described, the novelty of this research is the use of an Internet of Things (IoT)-based virtual science laboratory on nervous system material at the tertiary level. It can provide an alternative to practicum in online science courses amid the Covid-19 pandemic; therefore, this study will analyze the effectiveness of science learning on nervous system material using a virtual laboratory based on the Internet of Things (IoT). This study aims to evaluate the effectiveness of an IoT-based virtual science laboratory on nervous system material.

Research Method

The research method used was an experiment with a pretest-posttest control group design. The research subjects were A3 and A4 class students in the Universitas PGRI Yogyakarta PGSD study program who were randomly selected from students taking Science courses. The research subjects would be divided into two groups: the experimental and control groups. The experimental group would use an IoT-based virtual science laboratory on nervous system material. In contrast, the control group will use conventional learning methods without an IoT-based virtual science laboratory. Before the implementation of the treatment, a pretest would be conducted on both groups to measure students' understanding of the nervous system material. After that, the experimental group would be given treatment in the form of learning using an IoT-based virtual science laboratory on nervous system material for four weeks, while the control group will be given treatment in the form of conventional learning using textbooks and blackboards. After the learning period, a posttest would be conducted on both groups to measure students' understanding of the nervous system material

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after the treatment. In addition, a questionnaire would also be conducted to measure student satisfaction with using an IoT-based virtual science laboratory on nervous system material.

The data obtained would be analyzed using descriptive and inferential statistical analysis. Descriptive analysis was used to describe sample characteristics and questionnaire results. In contrast, inferential analysis was used to test differences in student understanding between experimental and control groups using independent t-tests. In addition, correlation analysis would also be conducted to determine the relationship between student satisfaction with the use of IoT-based virtual science laboratories and student understanding of nervous system material, and the N-Gain test will be conducted. The average value of N-Gain was calculated to see the increase in student understanding. The N-Gain value will show the effectiveness of using IoT-based virtual science laboratories in improving students' understanding of nervous system material. This study will also consider the ethical and security aspects of using IoT-based virtual science laboratories, such as student personal data and internet network security.

Results and Discussion

Internet of Things (IoT)-based virtual science laboratory on nervous system material is an educational technology innovation that utilizes the internet and IoT devices to provide students a more interactive and effective learning experience. This virtual science laboratory can be accessed through the internet network, allowing students to conduct experiments and simulations about the nervous system virtually. In this IoT-based virtual science laboratory, IoT devices are connected to the internet and integrated with the learning system. These devices can provide students with accurate and real-time information and data when conducting experiments and simulations in the virtual science laboratory. In learning about the nervous system, the IoT-based virtual science laboratory can show visualizations and allow students to learn how the nervous system works in the human body. In addition, this virtual science laboratory can also provide simulations of how the nervous system responds to stimuli from the external environment and how the nervous system interprets these stimuli.

Based on the research that the author has done, it is found that the IoT-based virtual science laboratory on nervous system material has several advantages, among others: First, students can access the virtual science laboratory from anywhere and anytime, making the learning process easier. Second, this virtual science laboratory can provide a more interactive learning experience and improve students' understanding of concepts. Third, this virtual science laboratory can reduce the cost and time required to conduct experiments in a physical laboratory.

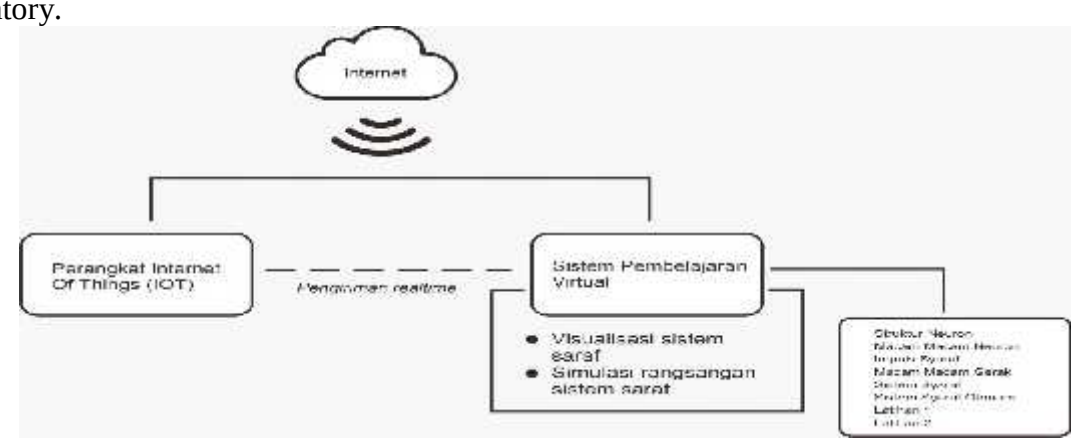

Figure 1. IoT-Based Science Laboratory Design on Nervous System Materials

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As for the laboratory display on the device (laptop, PC and cellphone) can be seen in Figures 2, 3, and 4 as follows.

Figure 2. Initial view & Material Page

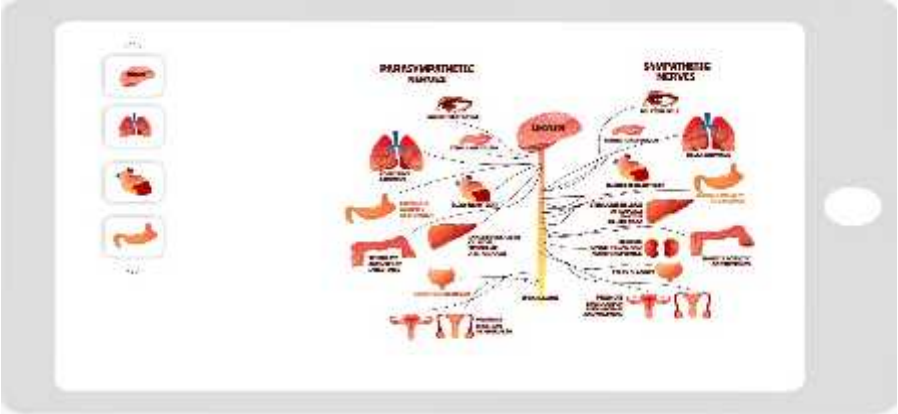

Figure 3. Practicum page

Based on Figures 2, 3, and 4, it is known that using an IoT-based virtual science laboratory on nervous system material can increase student interest and motivation in learning and improve student understanding and mastery of concepts in nervous system material. The Internet of Things (IoT)-based virtual science laboratory on nervous system material is an exciting concept in the development of educational technology. The results showed that the IoT-based virtual science laboratory on nervous system material effectively improved student learning outcomes, as evidenced by the higher average post-test score compared to the average pre-test score. It can be seen in the following table:

Table 1. Pretest and Posttest Results Student Material Understanding

No	Class	Average		Gain	Criteria
		Pre-Test	***Post-Test***		
1.	Control	46,86	64,27	0,32	Medium
2.	Experiment	44,00	84,77	0,72	High

Based on the table above, the average pretest score in the control class is 46.86. Then, after the learning process was carried out as usual for 3 lessons, the students did a posttest at the end of the meeting and got the class average value of 64.27. The pretest-posttest results showed that student understanding in the control class increased by 17.41 with a gain of 0.32. The increase is included in the low category. Besides this, the average pretest score in the experimental class was 44.00. Then, after implementing learning activities using a virtual science laboratory based on the Internet of Things (IoT) for three learning sessions, students

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do a posttest at the end of the meeting and get a class average score of 84.77. The pre-test-post-test results show that student understanding in the experimental class increased by 40.77 with a gain of 0.72. This increase is included in the high category. A clearer picture of the average posttest value of student understanding of nervous system material in the control and experimental classes can be seen in the following graphical image.

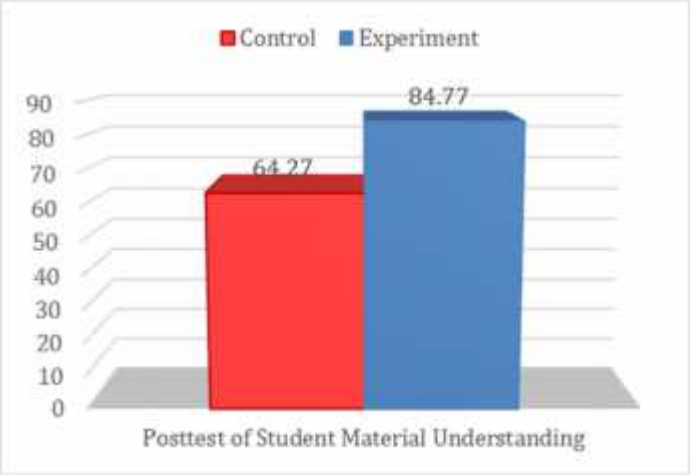

Figure 4. Comparison of posttest material understanding students in the control and experimental classes

In addition, this study also shows that the IoT-based virtual science laboratory can help students understand the material better and increase their interest in learning.

The t-test research data analysis showed a significant difference between the pretest and posttest results in the group using the IOT-based virtual science laboratory on nervous system material (significance value <0.05). It shows that using IOT-based virtual science laboratories in nervous system material can improve students' understanding. In addition, the n gain results show that the use of IOT-based virtual science laboratories on nervous system material provides a high increase in student understanding. The average increase in n gain in the group using the IOT-based virtual science laboratory was 0.72, which showed a significant increase in understanding. In terms of student responses to learning using an IOT-based virtual science laboratory on nervous system material, most students responded positively to using the virtual science laboratory. Students find it easier to understand the concepts in the nervous system material through virtual science laboratories and feel more interested and motivated to learn.

Learning using an IOT-based virtual science laboratory on nervous system material has several advantages over conventional learning conducted in a physical laboratory. Some advantages include the ability to conduct difficult or dangerous experiments virtually without safety risks and high costs, the use of technology that appeals to students, and greater flexibility of time and place. The use of virtual technology in learning has been shown to increase students' motivation and interest in learning science (Gaol, 2015; Hadi & Hermansyah, 2021; Suarja & Aswadi, 2016; Yuniarti et al., 2012). In addition, virtual science laboratories can provide a more fun and engaging learning experience, increasing student participation and improving learning outcomes. In the context of learning about the nervous system, IOT-based virtual science laboratories can provide a more immersive experience and help students better understand the nervous system concept. Students can learn about different parts of the nervous system and observe the interactions between them virtually, which can improve their understanding of complex concepts.

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Research on learning using IoT-based virtual science laboratories on nervous system material is a topic that continues to grow and attract attention in science education. The position of this research lies in the effort to improve the effectiveness of science learning through the use of evolving technologies, namely the Internet of Things (IoT) and virtual science laboratories. Supported by research conducted by (Fazilla, 2019), it has been proven that using technology in science learning can increase students' understanding and involvement in learning. One of the advantages of learning using an IoT-based virtual science laboratory on nervous system material is the ability to combine theoretical concepts with practical experiences that are directly involved through interactive simulations. In addition, the virtual science laboratory also allows students to conduct experiments that are impossible in a physical laboratory, such as visualizing how nerve signals work in real time through interactive simulations.

In this study, students were tested with several case studies that required problem-solving and critical thinking about the concept of the nervous system, and the results showed that students who used the IoT-based virtual science laboratory had better abilities than students who used the physical laboratory. Thus, the position of research on learning using IoT-based virtual science laboratories on nervous system material is as an effort to increase the effectiveness of science learning using technology that continues to grow, as well as overcome the limitations that may exist in physical laboratories. This research provides an alternative solution that can enrich students' learning experience and increase their involvement in science learning.

Learning research using IOT-based virtual science laboratories on nervous system material differs from previous similar studies. Previously, several similar studies have been conducted, such as research conducted by (Syam & Kurniasih, 2023; Athailah et al., 2017) using simulation or animation-based learning methods, but in this study, a virtual laboratory-based learning method with Internet of Things (IOT) technology is used. This research also emphasizes using IOT technology to support virtual laboratory learning, allowing students to conduct experiments independently and respond to data in real time. It differs from previous studies that rely only on simulations or animations that tend to be more static and less interactive. In addition, this research also pays attention to the factor of student involvement in learning, by integrating game features and competition elements in learning. It can increase students' motivation and encourage them to be more active in learning. Thus, research on learning using IOT-based virtual science laboratories on nervous system material has advantages in using technology that is more interactive, real-time, and able to increase student involvement in learning. These differences can be used as a basis for developing more effective and innovative learning approaches in the future.

Conclusion

Based on the study's results, the Internet of Things (IoT)-based virtual science laboratory on nervous system material effectively improves students' concept understanding. It can be seen from the average n-gain result of 0.72 in the experimental group, which shows a high increase in concept understanding. The t-test results showed significant differences between the control and experimental groups regarding the effectiveness of the IoT-based virtual science laboratory on nervous system material. Therefore, the IoT-based virtual science laboratory is a good alternative for learning nervous system material because it can improve students' understanding of concepts. This research is expected to contribute to developing educational technology that can improve the quality of learning.

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Recommendation

Based on the above conclusions, researchers suggest that for science teachers, it is hoped that this Internet of Things (IoT)-based virtual science laboratory can be used as one of the more effective and innovative learning media in the learning process of nervous system material. As for students, this virtual science laboratory media based on the Internet of Things (IoT) is expected to be maximally utilized by students so that it can help them more easily understand nervous system material. Furthermore, future researchers can develop a broader Internet of Things (IoT)-based virtual science laboratory by involving all classes and more than one educational institution to strengthen evidence of the effectiveness of the Internet of Things (IoT)-based virtual science laboratory on improving the science process skills of other students and further develop the Internet of Things (IoT)-based virtual science laboratory with as much interest as possible and on different materials.

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References

Abekiri, N., Rachdy, A., Ajaamoum, M., Nassiri, B., Elmahni, L., & Oubail, Y. (2023). Platform for hands-on remote labs based on the ESP32 and NOD-red. *Scientific African*, *19*. https://doi.org/10.1016/j.sciaf.2022.e01502

Agustina, M. (2018). Peran Laboratorium Ilmu Pengetahuan Alam (IPA) Dalam Pembelajaran IPA Madrasah Ibtidaiyah (MI) / Sekolah Dasar (SD). *At-Ta'dib: Jurnal Ilmiah Prodi Pendidikan Agama Islam*, *10*(1), 1–10. https://ejournal.staindirundeng.ac.id/index.php/tadib/article/view/110

Alatas, F., & Fachrunisa, Z. (2019). An Effective Of Pogil With Virtual Laboratory In Improving Science Process Skills And Attitudes: Simple Harmonic Motion Concept. *Edusains*, *10*(2), 327–334. https://doi.org/10.15408/es.v10i2.10239

Alhazmi, A. K., Kaed, E., Al-Hammadi, F., Alsakkaf, N., & Al-Hammadi, Y. (2023). The Internet of Things as a Tool Towards Smart Education: A Systematic Review. *Lecture Notes in Networks and Systems, 561 LNNS*. https://doi.org/10.1007/978-3-031-18344-7_45

Athailah, Khaldun, I., & Mursal. (2017). Peningkatan Pemahaman Konsep Siswa Melalui Laboratorium Virtual Pada Materi Listrik Dinamis Di Sma Negeri 1 Sukamakmur Aceh Besar. *Jurnal Pendidikan Sains Indonesia*, *5*(1), 114–119.

Aurelia, G. (2021). Pembelajaran hybrid pada masa pandemi. *Jurnal Pendidikan Bahasa Dan Sastra Indonesia*, *1*, 1–6.

Bahtiar, & Azmar. (2022). The Effect of Using a Virtual Laboratory on Students' Motivation and Learning Outcomes in Physics Learning. *Jurnal Pendidikan Fisika*, *10*(1).

Benesha, J., Lee, J., James, D. A., & White, B. (2020). *Are You for Real? Engineering a Virtual Lab for the Sports Sciences Using Wearables and IoT*. 110. https://doi.org/10.3390/proceedings2020049110

Bortnik, B., Stozhko, N., Pervukhina, I., Tchernysheva, A., & Belysheva, G. (2017). Effect of virtual analytical chemistry laboratory on enhancing student research skills and practices. *Research in Learning Technology*, *25*. https://doi.org/10.25304/rlt.v25.1968

Vol. 11 No. 1 : January 2024
E-ISSN: 2722-4627
pp. 71-80

Cîmpanu, C., Lupu, R. G., & Ungureanu, F. (2019). Laboratory of things: Virtual laboratory for signal processing experiments. *ELearning and Software for Education Conference*, 242–248. https://doi.org/10.12753/2066-026X-19-033

Fazilla, S. (2019). Pemanfaatan teknologi informasi (smartphone) terhadap kemampuan analisis mahasiswa dalam konsep dasar IPA. *Jurnal Pendidikan Dasar (JUPENDAS)*, *6*(1), 12–18. http://www.jfkip.umuslim.ac.id/index.php/jupendas/article/view/501

Gaffar, A. A., & Sugandi, M. K. (2019). Efektivitas Perangkat Pembelajaran Berbasis Praktikum Virtual untuk Meningkatkan Keterampilan Proses Sains Siswa SMA Pada Materi Invertebrata. *BIOSPER*.

Gaol, R. L. (2015). Peningkatan Kualitas Pembelajaran Listrik Dinamis Melalui Implementasi Virtual Laboratorium Berbasis Komputer Di Smp Negeri 9 Tebing Tinggi. *Jurnal Teknologi Informasi & Komunikasi Dalam Pendidikan*, *2*(1). https://doi.org/10.24114/jtikp.v2i1.3289

Hadi, S., & Hermansyah, H. (2021). pelatihan penggunaan aplikasi chemlab sebagai alternatif praktikum untuk meningkatkanketerampilan proses sains siswa SMAN 3 Lembar. *Jurnal Pengabdian Magister Pendidikan IPA*, *4*(2). https://doi.org/10.29303/jpmpi.v4i2.663

Handayani, D., & Alfina, V. D. (2021). Penerapan Media Pembelajaran Menggunakan Laboratorium Virtual Pada Masa Pandemi Covid-19. *Prosiding Webinar Nasional Pgri Provinsi Sumatera Selatan Dan Universitas Pgri Palembang*, *November*, 233–238.

Hewi, L., & Shaleh, M. (2020). Refleksi Hasil PISA (The Programme For International Student Assesment): Upaya Perbaikan Bertumpu Pada Pendidikan Anak Usia Dini). *Jurnal Golden Age*, *4*(01), 30–41. https://doi.org/10.29408/jga.v4i01.2018

Ilyas, I., Liu, A. N. A. M., & Sara, K. (2022). Efektivitas Penggunaan Laboratorium Virtual Berbasis Keterampilan Proses Sains Terintegrasi Zoom Meeting untuk Meningkatkan Pemahaman Konsep Fisika Siswa Pada Masa Pandemi Covid-19. *Jurnal Penelitian Pendidikan IPA*, *8*(5), 2235–2240. https://doi.org/10.29303/jppipa.v8i5.2073

Indarwati, D., Musyadad, F., & Utami, W. M. (2021). Urgensi media pembelajaran audio visual pada hasil belajar ilmu pengetahuan alam (IPA) di sekolah dasar. *Dikdastika: Jurnal Ilmiah Pendidikan Ke-SDan*, *7*(1), 23–30.

Leisenberg, M., & Stepponat, M. (2019). Internet of things remote labs: Experiences with data analysis experiments for students education. *IEEE Global Engineering Education Conference, EDUCON, April-2019*. https://doi.org/10.1109/EDUCON.2019.8725070

Musi, M. A., Bachtiar, M. Y., & Herlina. (2022). Pelatihan Pembelajaran Sains Satuan Pendidikan Anak Usia Dini. *SNPPM-4 (Seminar Nasional Penelitian Dan Pengabdian Kepada Masyarakat)*, *4*, 165–173. https://prosiding.ummetro.ac.id/index.php/snppm/article/view/74%0Ahttps://prosiding.ummetro.ac.id/index.php/snppm/article/download/74/38

Nisa, L. (2020). Pemanfaatan Teknologi Dalam Pendidikan Anak Usia Dini. *ThufuLA: Jurnal Inovasi Pendidikan Guru Raudhatul Athfal*, *8*(1), 1–14. https://doi.org/10.21043/thufula.v8i1.6283

Pongoh, D., & Budiman, M. (2022). *Rancang Bangun Sistem Pembelajaran Laboratorium Virtual Berbasis IoT (Internet Of Thing) di Laboratorium Konversi Energi ,*

Vol. 11 No. 1 : January 2024
E-ISSN: 2722-4627
pp. 71-80

Distribusi dan Proteksi. *1*(1).

Prabandari, F., & Sumarni, S. (2020). Pengaruh Persepsi E-Learning Terhadap Kepuasan Mahasiswa Kebidanan Dalam Masa Pandemik Di Stikes Muhammadiyah Gombong. *Jurnal Ilmiah Kesehatan Keperawatan*, *16*(1), 44. https://doi.org/10.26753/jikk.v16i1.401

Prihatmoko, D. (2016). Penerapan Internet Of Things (IoT) Dalam Pembelajaran Di Unisnu Jepara. *Simetris : Jurnal Teknik Mesin, Elektro Dan Ilmu Komputer*, *7*(2), 567. https://doi.org/10.24176/simet.v7i2.769

Raini, Y. (2020). Pengaruh Media Laboratorium Virtual (PhET) Terhadap Kemampuan Pratikum Kimia Siswa SMK Taruna Terpadu Bogor. *Jurnal Teknonologi Pendidikan*, *5*(2).

Raksa, M. (2020). Implementasi Workshop Pengembangan Keprofesionalismean Berkelanjutan Pendidikan Abad 21 untuk Meningkatkan Kinerja Guru. *Jurnal Pedagogi Dan Pembelajaran*, *3*(1), 1–14. https://doi.org/10.23887/jp2.v3i1.24355

Ramadiani, S., Silvianti, N., Putra, R. P., & Agustina, R. D. (2022). Uji Perbandingan Kegiatan Laboratorium berbasis IoT dengan Virtual Laboratory pada Materi Periode Bandul dengan HOTLAB. *Jurnal Penelitian Ilmu Pendidikan*, *15*(1). https://doi.org/10.21831/jpipfip.v15i1.41485

Rusliati, E., & Retnowati, R. (2019). Inkuiri Terbimbing Pada Laboratorium Virtual Dan Riil Untuk Membangun Penguasaan Konsep Dan Keterampilan Proses Sains. *Journal Of Science Education And Practice*, *3*(2), 46–55. https://doi.org/10.33751/jsep.v3i2.1857

Sarah, R. T. P. (2018). *Virtual Laboratory Terhadap Kemampuan Investigasi Dan Prestasi Belajar Peserta Didik the Effect of Applying Virtual Laboratory Towards Students '*. 184–192.

Suarja, Z. A., & Aswadi, C. (2016). Penggunaan Laboratorium Virtual Biologi Sebagai Sarana Praktikum Yang Efektif dan Efisien Untuk Mencapai Pengalaman Belajar yang Menyenangkan. *Jurnal Bio-Natural*, *3*(2), 80–89.

Sulthon, S. (2016). Pembelajaran IPA yang Efektif dan Menyenangkan bagi Siswa MI. *ELEMENTARY: Islamic Teacher Journal*, *4*(1), 38–54. https://doi.org/10.21043/elementary.v4i1.1969

Susdarwati, D., Agnafia, N., & Dimas, A. (2021). Workshop Pemanfaatan Laboratorium Virtual IPA Sebagai Media Pembelajaran di Masa Pandemi. *Indonesian Journal of Community Engagement (IJCE)*, *2*(2), 47–52.

Sutrisna, N. (2021). Analisis Kemampuan Literasi Sains Peserta Didik SMA Di Kota Sungai Penuh. *Jurnal Inovasi Penelitian*, *1*(12), 2683–2694. https://stp-mataram.e-journal.id/JIP/article/view/530

Syam, Y. R., & Kurniasih, S. (2023). Kebutuhan Terhadap Laboratorium Virtual Berbasis Masalah pada Materi Sistem Peredaran Darah. *Jurnal Imiah Pendidikan Dan Pembelajaran*, *7*(1), 166–172. https://doi.org/10.23887/jipp.v7i1.57970

Trisnawati, D., & Yetri, Y. (2019). Efektivitas Model NHT Berbantu Laboratorium Virtual Terhadap Hasil Belajar Ditinjau dari Keterampilan Proses Sains. *Indonesian Journal of Science and Mathematics Education*, *2*(2), 227–234. https://doi.org/10.24042/ijsme.v2i2.4329

Yuniarti, F., Dewi, P., & Susanti, R. (2012). Pengembangan Virtual Laboratory Sebagai Media Pembelajaran Berbasis Komputer Pada Materi Pembiakan Virus. *Journal of Biology Education*, *1*(1), 50229.

