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The Influence of Virtual Science Laboratory Design to Increase the Visual Literacy of Prospective Science Teachers

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Abstrack

This study aims to analyze the influence of Virtual Science Laboratory design on improving the visual literacy skills of prospective science teachers. Visual literacy is an essential competency in science education, as it enables learners to interpret, analyze, and communicate scientific information through visual representations. The study employed a quasi-experimental method using a Nonequivalent Control Group Design involving an experimental group that learned through a Virtual Science Laboratory and a control group that received conventional instruction. Both groups were administered pretests and posttests to measure changes in visual literacy achievement. Data were analyzed using the Kolmogorov–Smirnov test to examine data distribution, the Wilcoxon Signed Ranks Test to identify differences between pretest and posttest scores within groups, and the Mann–Whitney Test to compare learning outcomes between groups. The findings revealed that students in the experimental group demonstrated significantly higher improvements in visual literacy compared to those in the control group. The use of Virtual Science Laboratory media provided a more interactive, engaging, and technology-oriented learning experience, enabling prospective teachers to better understand and interpret scientific visual information. These results indicate that Virtual Science Laboratory design is an effective alternative learning medium for enhancing visual literacy skills among prospective science teachers. The study further highlights the need for continuous development of virtual laboratory content, teacher training, and broader implementation to support science education in the digital era.

Keywords: *Virtual Science Laboratory, Visual Literacy, Prospective Science Teachers, Science Education, Quasi-Experimental Study.*

Abstrak

Penelitian ini bertujuan untuk menganalisis pengaruh desain Virtual Science Laboratory terhadap peningkatan kemampuan literasi visual calon guru IPA. Literasi visual merupakan kompetensi penting dalam pembelajaran sains karena memungkinkan peserta didik memahami, menafsirkan, dan mengomunikasikan informasi ilmiah melalui berbagai representasi visual. Penelitian ini menggunakan metode kuasi-eksperimental dengan desain Nonequivalent Control Group Design yang melibatkan kelompok eksperimen yang memperoleh pembelajaran menggunakan Virtual Science Laboratory dan kelompok kontrol yang memperoleh pembelajaran konvensional. Kedua kelompok diberikan pretest dan posttest untuk mengukur perubahan kemampuan literasi visual. Analisis data dilakukan menggunakan uji Kolmogorov–Smirnov untuk menguji distribusi data, Uji Wilcoxon Signed Ranks untuk mengetahui perbedaan skor sebelum dan sesudah perlakuan dalam masing-masing kelompok, serta Uji Mann–Whitney untuk membandingkan hasil belajar antara kedua kelompok. Hasil penelitian menunjukkan bahwa kelompok eksperimen mengalami peningkatan kemampuan literasi visual yang lebih tinggi dan signifikan dibandingkan kelompok kontrol. Penggunaan Virtual Science Laboratory memberikan pengalaman belajar yang lebih interaktif, menarik, dan sesuai dengan perkembangan teknologi, sehingga membantu calon guru IPA dalam memahami serta menginterpretasikan informasi visual ilmiah secara lebih efektif. Temuan ini menunjukkan bahwa desain Virtual Science Laboratory merupakan alternatif media pembelajaran yang efektif untuk meningkatkan literasi visual calon guru IPA. Oleh karena itu, pengembangan konten, pelatihan pengguna, dan implementasi yang lebih luas perlu dilakukan guna mendukung pembelajaran sains di era digital.

Kata Kunci: *Virtual Science Laboratory, Literasi Visual, Calon Guru IPA, Pendidikan Sains, Kuasi-Eksperimental.*

A. Introduction

The unstoppable wave of globalization has brought major changes in thinking and performance, encouraging a shift from conventional systems to modernization to increase human resource competence. The development of information technology is growing increasingly rapidly, thus encouraging the creation of innovation in all fields, one of which is education. Technological developments require teachers to use various forms of media in learning.[1] Education is an important example in encouraging human development in various aspects such as insight, social awareness and environmental awareness during the Technology Era 4.0 revolution.[2]

The development of the Technology Era 4.0 has accelerated human thinking and performance in various domains of life, especially in the field of education.[3] Although formal education plays an important role in cultivating quality human capital, the unexpected global pandemic, COVID-19, has forced rapid and extensive adoption of technology to ensure future human capabilities.

Schools and universities in Indonesia, like many other universities around the world, have been greatly affected by the COVID-19 pandemic so face-to-face learning activities have been suspended indefinitely. This situation presents significant challenges for educators in conveying theoretical knowledge effectively. In response, there is an increasing need for strategic use of technology to support education.[4] As highlighted by Rahmattullah & Syamsu (2021), who suggested the inclusion of extracurricular activities regarding COVID-19 and Social Distancing to bridge the gap in traditional teaching.

Higher education institutions, especially faculties of education and natural sciences, rely heavily on laboratory practices to strengthen theoretical concepts.[5] This direct experience is very important to strengthen students' understanding. However, there are still significant

[1] Sugiani, K. A., Komputer, T., & Guru, P. G. (2019). Jurnal Ilmiah Pendidikan Citra Bakti Pengembangan Media Pembelajaran Berbasis Mobile Learning untuk Meningkatkan Kemampuan Literasi Visual dan Hasil Belajar. *Junal Ilmiah Pendidikan Citra Bakti*, 6(November), 110–120.

[2] Wahyuni, U. M., Rahmadoni, J., Kartika, A. D., Arifnur, A. A., Kamil, H., Silvana, M., Akbar, R., & Wahyudi, W. (2021). Literasi Visual Media Edukasi Poster Terkait Covid-19 Pada Siswa Sma Di Kota Padang. *Jurnal Hilirisasi IPTEKS*, 4(1), 82–91.

[3] Tangahu, W., Rahmat, A., & Husain, R. (2021). Modern Education in Revolution 4.0. *Website: Ijiert.Org VOLUME*, 8(1), 3–7.

[4] Zakaria, Z., Kurniawan, C., & Pratiwi, S. A. (2020). Literasi Visual Melihat Gambar Pemandangan Calon Guru Madrasah. *KNPI: Konferensi Nasional Pendidikan Islam*, February, 259–269.

[5] Aziz, F. A., & Halim, L. (2020). Concept Mapping Plays Important Roles on Students' Critical Thinking Skills in Science. *The Eurasia Proceedings of Educational & Social Sciences (EPESS)*, 17, 1–9.

challenges in laboratory management, as described by Nur'aisah et al. (2020), including planning, administration, program performance, and resource limitations.[6]

Effective laboratory management, integrated with technology, requires comprehensive program planning, covering personnel and administrative needs, such as standard operating procedures, budget planning, and equipment procurement.[7] However, as identified by Sutapa et al. (2020), practical sessions are sometimes conducted in regular classrooms rather than specialized laboratories, and even if laboratory facilities are available, they may not suit the student ratio. In addition, the lack of appropriate equipment and materials, as mentioned by Aimah & Rohmah (2020) and Gustini & Wulandari (2020), significantly hinders the effectiveness of laboratory work.[8]

To overcome this challenge, there is increasing awareness of the importance of using technology. Technology can greatly improve laboratory performance and is especially important during the COVID-19 pandemic. In addition, Indonesia's imminent entry into the ASEAN Economic Community[9] emphasizes the need for an educational curriculum to prepare graduates who have high competitiveness in the era of Industry 4.0 and Society 5.0.[10] This is in line with the 2020 curriculum reform known as the "Free Learning Campus" introduced by the Ministry of Education and Culture, as discussed by Siregar et al. (2020).

Facing challenges such as the COVID-19 pandemic, limited resources, and the demands of the Independent Learning Campus, an innovative approach is needed. The use of environmentally friendly materials and technology as described by Lasia et al. (2020), can minimize work accidents and make it easier to identify materials that are safe for experiments. Technology is invaluable in practical sessions, helping educators overcome equipment shortages, as noted by Wardono (2020) through the use of homemade digital microscopes.

Therefore, implementing distance learning technology, such as virtual laboratories, is a necessity. Posting et al. (2019) have reported positive responses to distance laboratory learning, and Sun et al. (2008) found that virtual laboratory learning improved students' knowledge, learning styles, and preferences. Virtual laboratory learning can be applied at all levels of education, from basic education to higher education, as stated by Alfarizi K et al. (2020).

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[6] Sari, W. K., & Nada, E. I. (2020). Analisis Literasi Digital Calon Guru Kimia Dalam Pelaksanaan Ppl Berbasis Virtual Di Masa Pandemi Covid-19. *Orbital: Jurnal Pendidikan Kimia*, 4(2), 111–121.

[7] artmann, C., Orli-Idrissi, Y., Pflieger, L. C. J., & Bannert, M. (2023). Imagine & immerse yourself: Does visuospatial imagery moderate learning in virtual reality? *Computers & Education*, 104909

[8] Afacan, Ö., & Gürel, İ. (2019). The Effect of Quantum Learning Model on Science Teacher Candidates' Self-Efficacy and Communication Skills. *Journal of Education and Training Studies*, 7(4), 86

[9] Plummer, M. G. (2006). The ASEAN Economic Community and the European Experience. *Journal of Asian Economics*, 17(1), 1-27.

[10] Sutarna, N., & Maryani, E. (2021). Literasi Spasial Mahasiswa Calon Guru Sekolah Dasar. *DWIJA CENDEKIA: Jurnal Riset Pedagogik*, 5(2), 351

There are two principal aspects of visual literacy; Firstly, visual is a language, just like verbal language which has vocabulary, grammar and syntax. For example, in images, elements such as color, light and shadow, line, and composition function as vocabulary that forms a visual message.[11] According to Sofiana (2018), literacy skills possessed by teachers are one of the key factors when teachers want to design, create, and use media. Furthermore, according to Mauldya (2021), the literacy skills possessed by teachers greatly influence the abilities and skills possessed by teachers at school.[12]

Virtual learning is not limited to delivering content; also require features for analyzing answers and submitting laboratory reports, as proposed by Rokhim et al. (2020). "Based on these considerations, this follow-up research is a test of the implementation of the use of the Natural Sciences Virtual Laboratory to improve visual abilities.

B. Research Methods

This research used a quasi-experimental method with a pretest-posttest nonequivalent control group design.[13] This design involved two groups: the experimental group exposed to virtual laboratory media and the control group receiving conventional learning. Both groups underwent a pretest and posttest to measure changes in visual literacy. The sample consisted of 34 prospective teacher students, with 16 in the experimental class and 18 in the control class. The research procedure included field studies to identify learning problems, designing media and compiling instruments, administering pretests, applying treatments (virtual laboratory in the experimental class and conventional learning in the control class), administering posttests, and analyzing data. The virtual science laboratory media developed included guidelines for use, teaching materials in video, text, and image formats, and had been validated by experts with a reliability value of 0.78, indicating it was suitable for use in the quasi-experimental research.

Data collection techniques used simple random sampling. Data analysis employed descriptive statistics to understand data characteristics, homogeneity tests to ensure similar variances between groups before treatment, and difference tests including the independent t-test, Mann-Whitney U test, and N-Gain. The N-Gain formula, calculated as {(Posttest - Pretest)} / {(100 - Pretest)}, was used to measure the increase in student understanding, with scores categorized as: N-Gain < 30 (Low Gain), 30 ≤ N-Gain < 70 (Moderate Gain). Effect size analysis using Cohen's d was also applied to measure the magnitude of differences between

[11] Aji, D. T. (2021). Literasi Visual sebagai Pendekatan dalam Pembelajaran Fotografi. *Rekam*, 17(2), 123–134.

[12] Maulyda, M. A., Ermiana, I., Erfan, M., & Asri Fauzi. (2021). Hubungan Kemampuan Literasi Dan Karakteristik Media Visual Yang Dihasilkan Calon Guru. *Journal of Elementary Education*, 04(05), 712–719.

[13] Syahrial (2019) as cited in the original text; Creswell, J. W. (2012). *Educational Research: Planning, Conducting, and Evaluating Quantitative and Qualitative Research* (4th ed.). Boston: Pearson.

groups. The t-test criteria stated that when the significance value is less than or equal to 0.05, there are significant differences between the two groups.

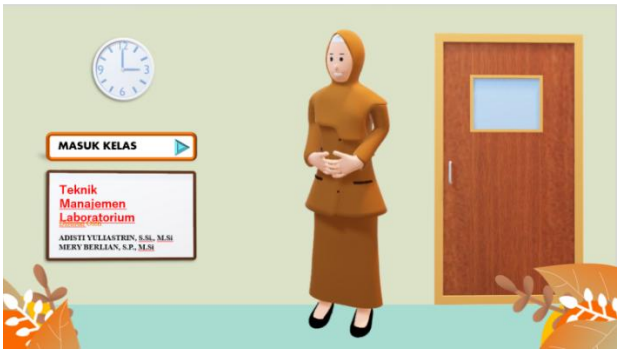
Controlling variables that could influence research results were also considered. Descriptive statistics helped understand the characteristics of the collected data, and the analysis results were used to draw conclusions based on research findings and their implications in the context of the problem being researched.

C. Pembahasan

1. Advantages of Virtual Science Laboratory-Based Textbook Media

The process of developing a Virtual Science Laboratory-based textbook has involved a series of stages that include analysis, design, development, implementation, and evaluation with full dedication. The result of this effort is a superior product in the form of a Virtual Science Laboratory-based textbook which provides teaching material facilities in various formats, including video, text, and images with a very high level of validity. In addition to meeting strict validity standards, this textbook also offers a high level of practicality, ensuring that its use can be easily integrated into the learning process.

Figure 1. *Science Laboratory Virtual Cover Design*



Not only that, the use of Virtual Science Laboratory-based textbooks has been empirically proven to be able to make a positive contribution in increasing the visual literacy of prospective teachers. The results of careful research show that the use of the Virtual Science Laboratory significantly improves students' visual literacy skills. The experimental class that used Virtual Laboratory media succeeded in achieving higher achievements in visual literacy assessments compared to the control class that did not use this media.

Figure 3. *Guidelines for Using Textbooks*

The increase in learning outcomes based on N-gain analysis shows that learning outcomes are in the high category, thus showing that there are differences in the pretest and posttest scores. Based on the results of the T-Test (Paired Sample T-test), it shows that there are significant differences, which can be seen from the increase in learning outcomes in the posttest. These findings confirm that the different approaches applied in the two groups have a significant impact on increasing the visual literacy competence of prospective teacher students.

2. Comparison of Visual Literacy Results Between Experimental and Control Class

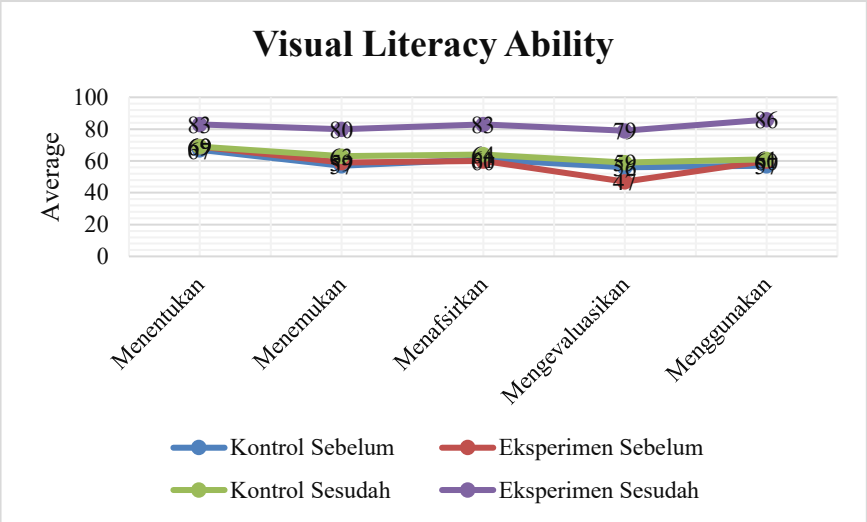
In Figure 5, it can be seen that before the different treatments were given between the experimental group and the control group, the curves representing the visual literacy abilities of the two classes were positioned close together, indicating similar levels of proficiency. However, after the application of different treatments, significant differences were visible in both curves. The experimental class showed significant improvement, with the curve centered on an average score of 80, while the control class remained at an average score of 70.

Figure 4. *Description of Experiment class activities*

This difference arises due to the use of virtual laboratory media which significantly increases students' visual literacy abilities. This media allows students to be more interactive and involved in the learning process, thereby facilitating better understanding

and interpretation of visual information. In addition, virtual laboratory media provides a more in-depth practical experience, which ultimately can improve students' visual literacy skills when dealing with learning material.[14]

Figure 5. *Visual Literacy Ability of Control and Experiment Class*



Research by Diwakar et al. (2023) explains that virtual laboratory media has a positive impact on laboratory performance. Apart from that, it can increase interest in learning,[15] and its ability to increase spatial presence and user involvement in learning, present spatial details, support understanding of semantic knowledge, and increase learning satisfaction.[16]

3. Understanding and Importance of Visual Literacy in Education

Visual literacy is an individual's capacity to understand and remember information presented in visual formats such as images, videos, or presentations. Visual media combines audio and visual elements so that it can increase students' visual literacy.[17] An individual's ability to capture and process information from visual media can be improved

[14] Handayani, D., & Alfina, V. D. (2021). Penerapan Media Pembelajaran Menggunakan Laboratorium Virtual Pada Masa Pandemi Covid-19. *Prosiding Seminar Nasional Program Pascasarjana Universitas Pgri Palembang*.

[15] Liu, C., & Huang, X. (2023). Does the selection of virtual reality video matter? A laboratory experimental study of the influences of arousal. *Journal of Hospitality and Tourism Management*, 54, 152–165.

[16] Hartmann, C., Orli-Idrissi, Y., Pflieger, L. C. J., & Bannert, M. (2023). Imagine & immerse yourself: Does visuospatial imagery moderate learning in virtual reality? *Computers & Education*, 104909

[17] Sukmadewi, L. P. M., & Suniasih, N. W. (2022). Media Audio Visual Berbasis Kontekstual pada Muatan IPA Meningkatkan Hasil Belajar Siswa. *Jurnal Pedagogi Dan Pembelajaran*, 5(1), 138–149.

through the concept of visual literacy, which includes skills related to reading and understanding messages conveyed through visual media.[18]

Visual literacy is an ability where individuals can recognize the use of lines, shapes, and colors so they can interpret actions, recognize objects, and understand symbolic messages. In general, visual literacy focuses on interpreting a person's visual images which is also related to reading and writing abilities. Visual literacy enables children who have just entered school to be able to arrange visual images of a story sequentially and correctly even though they cannot yet read.[19] Through visual literacy, even a small child who has not yet learned to walk will be able to organize his favorite books or various play equipment scattered around by adults.

By using the latest technology-based learning, students will certainly indulge their curiosity about knowledge. Therefore, based on this strong empirical evidence, Virtual Science Laboratory-based textbooks can be considered as an effective tool that supports improving the quality of learning in the field of natural sciences. The use of learning media can improve student learning outcomes because the use of media will involve students creatively in the learning process to develop their thinking abilities.

4. Effectiveness of Learning Media in Improving Learning Outcomes

According to Hamalik, the use of media can help the learning process become more effective and speed up the process of students' understanding of the learning material they are studying.[16] This is said to be effective because learning carried out using learning media can make learning less boring and fun so that students' interest and motivation to learn also increase. Virtual laboratory media allows students to be more interactive and involved in the learning process, thereby facilitating better understanding and interpretation of visual information.

By using virtual laboratory media, students gain a more in-depth practical experience, which ultimately can improve students' visual literacy skills when dealing with learning material. This is evidenced by the N-Gain results in the experimental class which reached an average of 57.14 (Medium category), while the control class only reached an average of 8.76 (Low category). The t-test results also showed a posttest significance value of 0.00 (< 0.05), indicating a significant difference in visual literacy between the control class and the experimental class after treatment.

[18] Yusa, I. M. M., & Putra, I. N. A. S. (2016). *Literasi Visual Tokoh Hanoman Bali dengan Pendekatan Augmented Reality*. An1mage.

[19] Anggraini, S. (2016). Budaya literasi dalam komunikasi. *WACANA: Jurnal Ilmiah Ilmu Komunikasi*, 15(3), 264–279.

Based on this strong empirical evidence, Virtual Science Laboratory-based textbooks can be considered as an effective tool that supports improving the quality of learning in the field of natural sciences. This is in line with the statement by Wahyuningtyas (2020) and Kristanto & Susilo (2016) that the use of learning media can improve student learning outcomes because the use of media will involve students creatively in the learning process to develop their thinking abilities, resulting in an increase in student learning outcomes.

D. Conclusions

The results of this research show that the experimental class using the virtual laboratory design has better results in increasing the visual literacy of prospective teachers. This is a learning alternative that is modern and up to date and in line with technological developments and the times. Based on these findings, it can be concluded that virtual laboratory media is effective in improving visual literacy skills compared to conventional learning methods. The experimental class achieved higher average scores and showed significant improvement, while the control class remained at a lower level of visual literacy. This implies that first, there is a need to develop further content in the Virtual Science Laboratory textbook to enrich the learning experience. Second, the importance of training for teachers so that they can use this textbook effectively. Third, regular evaluation is needed to improve the use of this textbook. Fourth, it is necessary to consider developing an interactive platform to support collaborative learning. Fifth, further research needs to be carried out to understand the potential application of the Virtual Science Laboratory in various learning contexts. Sixth, broad access must be provided to all prospective teacher students. Finally, collaboration with industry and other educational institutions can enrich the content and relevance of this textbook. By implementing these suggestions, the Virtual Science Laboratory textbook can continue to improve education in the field of natural sciences, especially as it has been proven through empirical evidence to increase visual literacy.

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