The Effectiveness of Virtual Laboratory Integrated Blacksmith Ethnophysics in Enhancing Data Literacy and Graphic Representation Skills

Christa Triana Dewi[1,*], Heru Kuswanto[1], Anggi Datiatur Rahmat[2], and Sihana[3]

[1]Physics Education Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia
[2]Science Education Department, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia
[3]SMA Negeri 1 Surakarta, Surakarta, Indonesia
Email: christatriana.2021@student.uny.ac.id (C.T.D.); herukus61@uny.ac.id (H.K.); anggidatiatur.2022@student.uny.ac.id (A.D.R.); sihanasmansa@gmail.com (S.)
*Corresponding author

Manuscript received November 15, 2023; revised February 5, 2024; accepted February 27, 2024; published August 23, 2024

***Abstract*—This study aims to investigate the effectiveness of a virtual laboratory integrated Blacksmith ethnophysics in enhancing data literacy and graphic representation skills. Blacksmith is one of the ethnophysics that explains the concept of heat. Experimental activities for this concept cannot be physically conducted in a laboratory, thus requiring technological assistance like a virtual laboratory. The virtual laboratory can be operated on smartphones. This study used a quasi-experimental design on an 11th-grade science class at one of the senior high school in Surakarta, Central Java, Indonesia. Learning activities in the experimental class used a virtual laboratory, and control class used paper worksheets. Data were collected through pre-and post-tests. The data analysis techniques include paired sample t-test, N-gain, and MANOVA statistical tests. The results found that students in the experimental class had higher scores on data literacy and graphic representation skills than those in the control class. N-gain scores for data literacy and graphic representation skills in the experimental class were 0.73 and 0.74, respectively, and categorized as a high category. The MANOVA test statistically found a significant difference in data literacy and graphic representation skills. The effectiveness of the virtual laboratory in enhancing data literacy and graphic representation skills in the experimental and control classes with scores of 93.6% and 96.7%, respectively. It can be interpreted that a virtual laboratory integrated Blacksmith ethnophysics effectively enhances data literacy and graphic representation skills.**

***Keywords*—Blacksmith, data literacy, ethnophysics, graphic representation, virtual laboratory**

I. Introduction

The tremendous development of technology has influenced all aspects of life, including education. Students need to be prepared for new literacy skills, including data, technology, and human literacy [1]. Data literacy skills are essential in the current era for collecting, managing, evaluating, and applying data critically [2]. Students need to be trained in investigating a phenomenon, starting from planning, collecting data, analyzing data, interpreting data, and creating conclusions [3]. Data literacy is essential for students as evidence supporting scientific reasoning and explanations [4]. Some studies findings data literacy in secondary schools still needs improvement [5, 6] and teacher-centered learning results in insufficient data literacy [7, 8].

Representation information is an important competency factor in conceptual understanding and scientific reasoning [9]. The interpretation of graphs plays a crucial role in education because it is relevant for understanding and representing data and comprehending concepts in various domains [10]. Efficient presentation of information for easy comprehension is also necessary for students in the current era. Previous studies found that students have difficulty representing information in other representations, such as graphics [11, 12]. Other studies have identified that students' graphic representation skills still need to improve, particularly in understanding kinematic graphs [13], and students find challenges in reading, creating, and interpreting graphs [14].

Contextual physics learning based on real-life problems positively impacts students' conceptual understanding [15]. Ethnophysics is a form of contextual learning that transforms indigenous science consisting of all knowledge about the actions of society derived from hereditary beliefs and cultures. Integrating local wisdom into physics learning can build a learning environment that relates to students' daily life [16]. Ethnophysics can encourage students to contemplate more complex ideas. Heat is a physics concept that is challenging for students to comprehend. Understanding the topic of heat requires skills in data literacy and graphical representation. Ethnophysics that can facilitate the understanding of the heat concept is *Pandai Besi* (Blacksmith), where the metalworking activity involves shaping metal into tools such as knives and machetes. Blacksmith is a local culture that is almost marginalized and it can give students experience relating to concrete, real-life examples in physics concepts. Integration of ethnophysics into the school curriculum creates effective hybridization, incubation, skill acquisition, and sustainable development for skill acquisition among secondary schools [17].

Ethnophysics learning is conducted through a Problem-Based Learning (PBL) model involving stages such as understanding the problem, collecting data, analyzing, discussing, and reflecting [18]. Previous research indicates that implementing a technology-based interactive media-integrated PBL model enhances students' conceptual understanding [19, 20]. Students can learn physics in a context that is relevant to their local culture using PBL. Blacksmith is a cultural tradition that involves the skill in making traditional weapons such as knives and machetes. Students can be trained to solve problems related to the Blacksmith ethnophysics.

Integrating technology into education has a positive impact on students' learning achievement. A smartphone is one of the technologies that has developed significantly and is

doi: 10.18178/ijiet.2024.14.8.2144

widely used by students. Virtual Laboratory (VL) is a tool for practical learning and facilitates experimental activities that are challenging to conduct in a physical laboratory [21]. Laboratory activities contribute to the improvement of students' data literacy [22]. VL can enhance students' understanding of concepts [23]. Also, VL has the advantage of aiding in the visualization and fostering the creativity of students [24], being user-friendly [25, 26] and an alternative for distance learning [27]. Besides, VL can serve as a solution for schools where science laboratory equipment and materials still need improvement [28].

Blacksmith is utilized as an ethnophysics to teach the concept of heat in physics. The Blacksmith process is identified as the problem to be investigated in experiments using VL. This activity is designed to enhance students' data literacy and graphic representation skills. This research aims to determine the effectiveness of the VL-integrated Blacksmith ethnophysics in enhancing data literacy and graphic representation skills.

II. Literature Review

A. *Data Literacy*

Data literacy is one of the skills that should be emphasized in physics learning. Data literacy plays a role in fostering critical thinking and problem-solving in daily life [29]. Data literacy is collecting, managing, evaluating, and applying data critically [30]. Data literacy is necessary to understand and effectively use data in decision-making [31]. If successfully developed, data literacy is a fundamental skill that can make it easier to achieve other skills [32]. Indicators of data literacy in this study: (1) data collection, (2) data analysis, (3) data interpretation, and (4) data implementation.

B. *Graphic Representation*

Graphs are one of the types of representation for summarizing data, processing, and interpreting information from complex data. Students are encouraged to interpret meaning based on information or relationships between variables obtained from the graph and problem-solving [10]. Representations such as diagrams and graphs are essential for effective interactive student engagement in physics learning. In addition, graphs are crucial in physics learning as a principle of proportionality to describe physical proportions [33]. Indicators of graphic representation in this study: (1) presenting data in graphical form, (2) interpreting relationships between variables, (3) extrapolation of making predictions, and (4) problem-solving.

C. *Virtual Laboratory*

Integrating technology is essential in 21st-century learning. Virtual Laboratory (VL) is a technology that can facilitate experimental activities in physics education. VL provides a learning experience that simulates an authentic laboratory by simulating and visualizing concepts and theories [34, 35]. The advantages of VL include overcoming limited resources, complex visualization, showing specific concepts for more detailed analysis, flexibility, and making experiments enjoyable [35]. The device used to operate VL is a smartphone that can be operated on Android. The application used to develop the virtual laboratory is the Android Studio software. Android Studio offers numerous features to enhance productivity when creating Android applications [36].

D. *Ethnophysics Blacksmith*

Etnophysics is an instructional approach that connects local culture, traditions, and scientific knowledge [37]. The other meaning, Ethnophysics is physics learning based on local wisdom that transforms original physics with people's beliefs or culture in applying it to scientific concepts [38–40]. Blacksmith involves metal shaping into iron tools such as knives, hoes, and hammers [41]. In this study, the etnophysics investigation focuses on physics concepts related to heat. In the Blacksmith process, the conceptual study encompasses the expansion of metal, conduction, and Black's principle. The etnophysics study in blacksmithing activities is shown in Table 1.

Table 1. Detail of etnophysics Blacksmith

No	Process of Blacksmith	The Aim of Activity	Physics Concepts
1	Heating 	Metal is heated until it becomes red-hot, causing the metal to expand and the metal structure to become more malleable for shaping.	In this process, the metal undergoes expansive expansion due to heating or the application of treatment to increase the metal temperature
2	Forging 	In this stage, the metal is placed on a base and struck with a forging hammer. The objective is to shape the metal according to the product type.	In this process, the red-hot metal is held with tongs/chisels to prevent the Blacksmith's hands from feeling the high heat. The contact between the tongs/chisels and the red-hot metal is called the conduction event.
3	Quick dipping (quenching) 	In this process, annealing is performed after the metal is forged, followed by a quick dipping (quenching) into a water bath. The purpose is to harden the metal material.	In this process, the quick dipping (quenching) event is carried out using the principles of Black's law because heat is released and absorbed. Heat is released by the high-temperature metal and absorbed by the low-temperature water, resulting in a thermal equilibrium between the two objects.

III. Materials and Methods

A. *Research Design*

This study was based on a quasi-experiment. The pre-and post-test control group design was used in this study. The research was conducted at SMA Negeri 1 Surakarta, Central Java, Indonesia. Pre- and post-tests were administered before and after students' participation in the physics learning activity. This design had two groups: experimental and control class. Both classes took "heat" courses in physics class. The experiment class used a virtual lab integrated Blacksmith ethnophysics, and the control class used worksheets paper. Data Literacy (DL) and Graphic Representation (GR) were applied to all classes before and after the implementation of this study. The design research of this study is shown in Fig. 1.

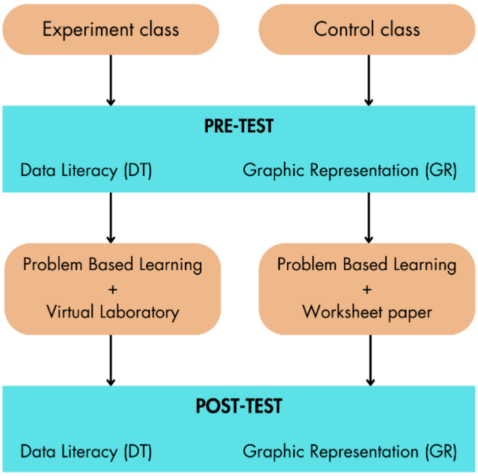


Fig 1. The research design of this study.

Based on the research design, the experiment class uses VL, and the control classes use worksheet paper. Both experimental and control classes use problem-based learning models with syntax as follows: (1) Orientation: Students give problems by observing blacksmith videos and understanding problems related to the concept of heat; (2) Organize: Students look for references about the concept of heat based on videos that have been observed; (3) Investigation: Students experiment using VL in experiment class and discuss using the worksheets in the control class; (4) Presenting: Students are conducting experiments and identified data and presenting results in graph analysis; (5) Analyzing and Evaluating: Students present the discussion results, and other students and teachers carry out a feedback process.

B. Participants

A total of 70 students from two classes of 11th graders of a senior high school at Surakarta, Central Java, Indonesia. The research participant was selected by random cluster sampling. The demographic characteristics of student distribution regarding gender is given in Table 2.

Table 2. Demographic characteristics of research participants

Group	Girl	Boy	Total
Experiment	20	16	36
Control	13	21	34

C. Design of VL-Integrated Blacksmith Ethnophysics

Firstly, the topic of "heat" was chosen because of its potential to increase students' interest. This topic is classified as abstract content, and heat experiments are considered hazardous when conducted in a classroom setting. Therefore, a virtual laboratory can serve as a solution to simulate experiments. Integrating Blacksmith ethnophysics into physics class to introduce local culture to students. Blacksmith was chosen as one of the local cultures suitable for the virtual laboratory due to the limitations of experimental equipment and the potential dangers associated with experimenting in the classroom. The virtual laboratory developed is named 'ETNOFISLAB' (an acronym for Etnophysics virtual lab). The design of ETNOFISLAB is shown in Fig. 2.

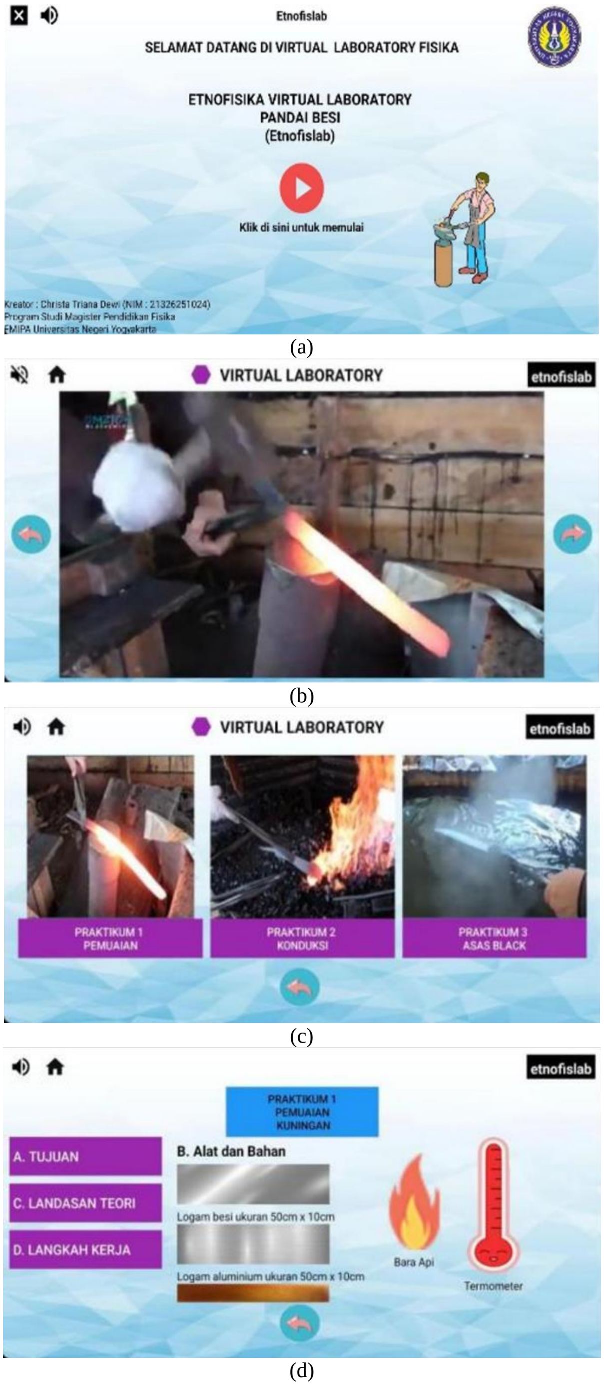


Fig. 2. The design of ETNOFISLAB, (a) splash screen, (b) video, (c) menu, and (d) experiments.

D. Data Collection Instruments

The instruments used in this research are pre-test and post-test to investigate the effectiveness of VL-integrated blacksmith ethnophysics on data literacy and graphic representation skills. The instrument consists of four essay questions related to the indicator of data literacy and four essays related to the indicator of graphic representation skills. **The indicators were selected based on the relevance of the content integrated in blacksmith ethnophysics.** Two lecturers and two practitioners as experts have validated the instrument. Question indicators in this study are shown in Table 3.

Table 3. Indicator of data literacy and graphical representation

Research variable	Indicator	Question Indicator
Data Literacy	Data Collection	Students can identify relevant data sources and appropriate data collection methods.
	Data Analysis	Students can analyze the data provided, such as performing simple calculations or identifying patterns within the data.
	Data Interpretation	Students can interpret the results of data analysis and draw accurate conclusions from the provided data.
	Data Implementation	Students can apply the results of data analysis in the context of a particular situation or problem.
Graphic Representation	Presenting Data in Graphical Form	Students can transform textual data into appropriate graphical representations, such as bar charts, line graphs, or pie charts.
	Interpreting Relationships Between Variables	Students can interpret relationships between variables displayed in graphs, such as identifying trends, comparisons, or correlations.
	Extrapolation or Making Predictions	Students can use a graph to extrapolate data or make predictions based on patterns observed in the graph.
	Problem-Solving	Students can use information from a graph to solve problems or answer questions related to the presented data.

E. Data Analysis

The research data were obtained from pre- and post-tests. The descriptive and predictive analyses were conducted in this study. Data have been observed following a normal distribution with a scatter plot between qi and Mahalanobis distance tends to form a straight line, whereas homogeneous based on the Box's M test if sig > 0.05.

Then, p-values and a paired sample t-test were used to determine the difference between experimental and control classes. Also, describe the comparison between the pre-and post-test, using the normalized gain. The formula for calculating the normalized gain is presented in Eq. (1), and the criteria for the normalized gain (N-gain) score are presented in Table 4. Furthermore, to determine the effect on each class using MANOVA. The software used for data analysis is SPSS 25.

$$g = \frac{S_f - S_i}{100 - S_i} \quad (1)$$

where:

$$S_f = final\ test(\ post - test\ score)$$

$$S_i = initial\ test\ (pre - test\ score)$$

$$g = gain\ (improvement)$$

Table 4. Gain value criteria [42]

No	Gain Value	Criteria
1	g ≥ 0.70	High
2	0.30 ≤ g < 0.70	Moderate
3	g < 0.30	Low

IV. Result and Discussion

The virtual laboratory integrated Blacksmith ethnophysics was developed and named ETNOFISLAB (Fig. 2). A virtual laboratory was implemented in the experiment class. ETNOFISLAB is designed to enhance data literacy and graphic representation skills. Detailed information on data literacy and graphic representation skills of those experiment and control classes can be found in Table 5.

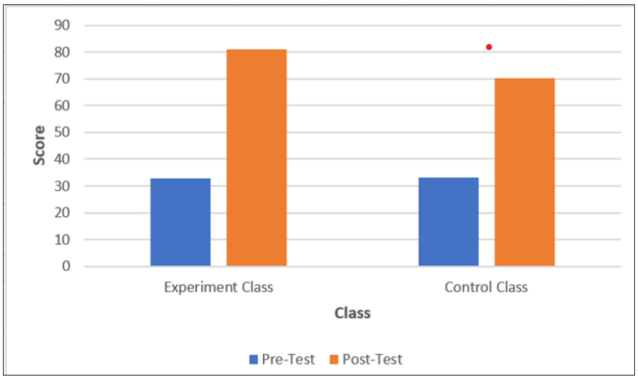
Table 5. Data Literacy and Graphic Representation of students in the experiment and control group

Skills	Group	Data	N	Mean	SD	t	p	N-Gain	Category
Data Literacy	Experiment	Pre-test	36	32.86	11.919	−30.590	0.013	0.73	High
		Post-test	36	81.00	11.389				
	Control	Pre-test	34	33.06	12.078	−60.000	0.000	0.57	Moderate
		Post-test	34	70.32	11.467				
Graphic Representation	Experiment	Pre-test	36	20.39	10.621	−24.467	0.000	0.74	High
		Post-test	36	78.50	11.538				
	Control	Pre-test	34	20.12	9.844	−28.152	0.000	0.58	Moderate
		Post-test	34	65.68	11.232				

Table 5 shows an increase in the average pre-test and post-test scores, and it indicates increased students' data literacy and graphic representation skills in experimental and control classes. Data literacy skills in the experimental class (t = –30.590, $p < 0.05$) and the control class (t = –60.000, $p < 0.05$). Also, graphic representation skills in the experimental class (t = −24.467, $p < 0.05$) and the control class (t = –28.152, $p < 0.05$). The results found that the experimental class significantly improved compared to the control class. Students in the experimental class scored higher on data literacy and graphic representation skills than those in the control class. This difference can be interpreted as evidence of the positive effects of implementing virtual laboratory-integrated Blacksmith ethnophysics.

Implementing VL-integrated blacksmith ethnophysics is a topic discussed in the experimental class. This topic was developed and implemented in the experimental class and is exciting for students. Most of it contains technology-based experimental activities through virtual laboratories, which were initially impossible to carry out in the classroom, have become realized and can create meaningful learning [43, 44].

This increase aligns with the calculation of the N-gain value where the experimental class data literacy skills score 0.73 in the high category, and the experimental class scores 0.57 in the medium category. Also, the graphic representation skills in the experimental class scored 0.74 in the high category, and the control class scored 0.58 in the medium category. This indicates that the improvement in data literacy and graphic representation skills in the experimental class is higher than in the control class. These findings align with the effectiveness of Android-assisted Benthik games in improving vector representation and critical thinking [45]. This indicates that the virtual laboratory integrated blacksmith ethnophysics effectively enhances data literacy and graphic representation skills. The improvement of students' data literacy and graphic representation skills is shown in Fig. 3.



(a)

(b)

Fig. 3. The improvement in each class. (a) data literacy and (b) graph representation.

Testing was conducted using the MANOVA to determine the impact of the VL-integrated Blacksmith ethnophysics on data literacy and graphic representation skills simultaneously. Several assumptions must be fulfilled before performing the MANOVA test. First, data to be tested with MANOVA must exhibit multivariate normality. This testing is carried out by creating a scatter plot of Chi-Square (qi) versus Mahalanobis distance, as shown in Fig. 4. The formed scatter plot tends to form a straight line, so it can be interpreted that the data is a multivariate normal distribution.

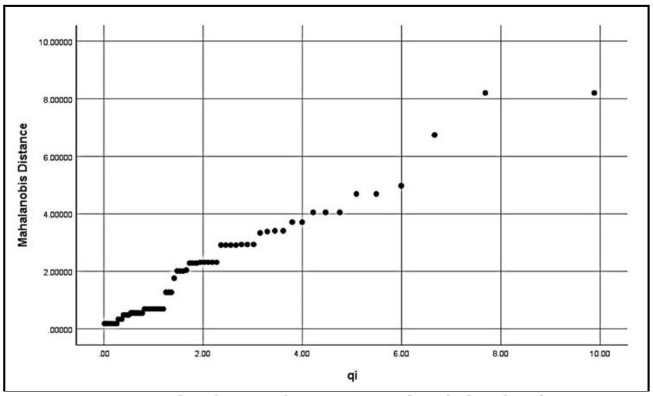


Fig. 4. Scatter plot showing between qi and Mahalanobis distance.

Another assumption that must be satisfied is homogeneity using Box's M test of equality of variance matrices. The homogeneity test results are presented in Table 6. The Box's M test result indicates a sig. of 0.882. This signifies that the assumption of equal population covariance matrices is satisfied, thus allowing the interpretation that the assumption of data homogeneity is fulfilled.

Table 6. Box's M test of equality of variance matrices

Box's M	Sig.
F	0.220
df1	3
df2	933697.455
Sig.	0.882

The assumptions for the MANOVA test have been satisfied. The test results are presented in Table 7. The hypotheses for this study are as follows:

H_0: There is no significant difference in data literacy and graphic representation skills simultaneously between the experimental and control groups.

H_1: There is a significant difference in data literacy and graphic representation skills simultaneously between the experimental and control groups.

Table 7. Result of MANOVA test

	Value	F	df Hypothesis	df Error	Sig.
Pillai's Trace	0.249	11.125[b]	2.000	67.000	0.000
Wilks' Lambda	0.751	11.125[b]	2.000	67.000	0.000
Hotelling's Trace	0.332	11.125[b]	2.000	67.000	0.000
Roy's Largest Root	0.332	11.125[b]	2.000	67.000	0.000

b indicates the exact statistic.

Based on calculations, the probability value of Wilks' Lambda (Sig.) is 0.000. This value is below the significance level $\alpha = 0.05$, thus rejecting the null hypothesis H_0. It can be interpreted that there is a significant difference in the simultaneous improvement of data literacy and graphic representation skills between the experimental and control groups, with $F = 11.125$, p-value < 0.05, where Wilks' Lambda = 0.751. A between-subject effects test was conducted to identify the mean differences for each variable between the experimental and control classes, as shown in Table 8.

Table 8. Tests of between-subjects effects

Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Data Literacy	1993.145	1	1993.145	15.264	0.000
Graphic Representation	2875.402	1	2875.402	22.162	0.000

Data literacy and graphic representation skills have a significance value of 0.00, less than 0.05. This implies a significant difference in data literacy and graphic representation skills between the experimental and control groups. These results indicate that implementing a virtual laboratory integrated Blacksmith ethnophysics effectively enhances data literacy and graphical representation skills. A General Linear Model (GLM), specifically in Hotelling's Trace multivariate test, was conducted to determine the effective contribution in each class. The result of the Hotelling's Trace multivariate test analysis is shown in Table 9.

Table 9. Result of Hotelling's trace multivariate test analysis

Variable	Class	F	Sig.	Partial Eta Squared
Data Literacy	Experiment	991.256	0.000	0.936
	Control	561.003	0.000	0.892
Graphic Representation	Experiment	2007.474	0.000	0.967
	Control	1165.341	0.000	0.945

The study results indicate differences in data literacy and graphic representation skills between the experimental and control classes. The effective contribution of the experimental and control classes to improving data literacy is 93.6% and 89.2%, respectively. Meanwhile, the effective contribution of the experimental and control classes to improving graphic representation skills is 96.7% and 94.5%, respectively. It can be interpreted that the class experiment that implemented the virtual laboratory integrated blacksmith ethnophysics is proven effective compared to control classes.

Based on the results of the MANOVA test, a significant influence was found on data literacy and graphic representation skills simultaneously. The test results confirm that the experimental class using the VL-integrated blacksmith ethnophysics effectively enhances data literacy and graphic representation skills. These findings indicate that the use of technology in physics education has a positive impact [46]. Students are more engaged in learning when recent technology is involved [47]. Technology has a positive impact on increasing students' motivation to learn [48]

Implementing a virtual laboratory can enhance data literacy. VL can provide visualizations that assist students in processing data, facilitating data literacy during experimental activities [49, 50]. Additionally, the use of a VL can also facilitate graphic representation [51, 52]. The virtual laboratory can display experimental data, allowing students to process the data into various representations. Graphic representation is crucial in physics experiments as it can reconstruct scientific knowledge [53, 54]. Previous studies found that virtual laboratories can enhance data literacy [55, 56]

Local culture is often marginalized, so there is a need to find ways to sustain and introduce it to the current generation. One way to achieve this is by integrating local culture into the school curriculum, including the learning process [57]. Learning activities related to students' daily lives based on their area of residence can help construct local knowledge into scientific knowledge [58–60]. It supports the integration of *Pandai Besi* (Blacksmith) in Surakarta in this study. The integration of technology and local culture into physics learning has a positive impact on student learning achievements [61]. Learning from the surrounding environment can create meaningful learning. Students can observe a scientific phenomenon directly and stimulate interest, curiosity, and critical thinking skills [62].

Using a virtual laboratory in physics learning can help students understand physics concepts more efficiently [63], simulate experimental activities that are impossible to do in class [23, 64], view abstract phenomena through simulations [50, 65] and achieve more meaningful learning. Virtual laboratories have the potential to increase student data literacy through experimental activities carried out. Integrating technology supports learners to develop skills and knowledge that can be learned in other technology-enhanced learning settings but more efficiently through unique experiences [66, 67].

The significant difference between experimental and control classes in data literacy and graphic representation skills shows that VL-integrated ethnophysics blacksmith scores higher than worksheets paper. These results are relevant to research that shows that VL positively impacts learning achievement compared to traditional methods such as paper worksheets. Previous research found that technology-based learning media can enhance students' graphic representation skills [68]. VL can present data experiments, thereby improving students' data literacy skills [69]. The correlation between students' data literacy and graphic representation skills on the implementation of the VL-integrated blacksmith ethnophyiscs was examined in this study. There is a significant correlation between data literacy and graphic representation skills. This study found that VL-integrated blacksmith ethnophysics effectively enhances data literacy and graphic representation. Thus, students who study physics using VL-integrated blacksmith ethnophysics have better on data literacy and graphic representation skills.

The limitation of the study is that it has a limited sample, focusing only on one specific area, namely Surakarta, Central Java, Indonesia. The local culture employed is familiar to students in their region. Even though the local culture in the area is familiar, today's students are part of the millennial generation, who need to become more familiar with it due to the influence of globalization. Integrating local culture into learning activities is one of the methods to ensure the preservation of cultural heritage. Selecting local culture that is adapted as ethnophysics in school curriculum will create a meaningful learning experience to make local culture better known globally. Although, integrated local culture in physics learning can be applied in other areas, it requires an introduction to the culture so that students can get to know it. Teachers can provide an overview of local culture at the beginning of the learning process as an orientation to increase students' learning motivation. In addition, VL was developed in this study only available on Android. This is a weakness because students who use iOS cannot operate it, they have to share with students Android users. Future research can develop VL that can be accessed on multi-platforms including iOS and Android.

Suggestions for further research include integrating the local cultures of other regions that are relevant to the students' backgrounds. In addition, testing the effectiveness of integrating local culture in areas that were previously unfamiliar with that culture will contribute to making local culture more global and known to the general public. Future research can investigate how integrating local culture into physics learning improves other skills, such as multi-representation involving images, mathematics, and verbal. Further investigation into the influence of local culture on 21st-century skills is also recommended.

V. Conclusion

Integrating technology and local culture can create meaningful learning. A virtual laboratory integrated blacksmith ethnophysics called ETNOFISLAB was developed and implemented in the experimental class. The results found that students in the experiment class scored more on data literacy and graphic representation skills than in the control class. N-gain scores in the experimental class on data literacy and graphic representation skills were 0.73 and 0.74, respectively, categorized in the high category. The MANOVA test statistically found a significant difference in data literacy and graphic representation skills. The effectiveness of the virtual laboratory in enhancing data literacy and graphic representation skills in the experimental and control classes with scores of 93.6% and 96.7%, respectively. Therefore, virtual laboratory-integrated Blacksmith ethnophysics effectively enhances data literacy and graphic representation skills in physics learning. The results of this study can be used as a reference for integrating technology and other ethnophysics.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

CTD discovered problems regarding physics learning in schools, compiled research instruments, designed a virtual laboratory, retrieved research data, analyzed data, and compiled reports. HK reviewed and monitored the research progress and provided input on the research. ADR reviewed and edited the language and reviewed the compiled articles, and S assisted in data collection. All authors had approved the final version.

Funding

This work was supported by the Indonesian Ministry of Education, Culture, Research, and Technology for funding this study through a PTM (*Penelitian Tesis Magister*) scheme with grant number T/13.80/UN34.9/PT.01.03/2023.

Acknowledgment

The authors wish to thank Universitas Negeri Yogyakarta and SMA Negeri 1 Surakarta for contributing to this research.

References

[1] Y. Cui, F. Chen, A. Lutsyk, J. P. Leighton, and M. Cutumisu, "Data literacy assessments: A systematic literature review," *Assess Educ.*, vol. 30, no. 1, pp. 76–96, 2023.

[2] C. Risdale, J. Rothwelll, M. Smit, and H. Ali-Hassan, *Strategies and Best Practices for Data Literacy Education: Knowledge Synthesis Report*, 2015.

[3] Suryadi, I. K. Mahardika, Supeno, and Sudarti, "Data literacy of high school students on physics learning," *Journal of Physics: Conference Series*, 2021. doi: 10.1088/1742-6596/1839/1/012025

[4] A. Wolff, M. Wermelinger, and M. Petre, "Exploring design principles for data literacy activities to support children's inquiries from complex data," *Int. J. Hum. Comput. Stud.*, vol. 129, pp. 41–54, 2019.

[5] E. H. Gebre, "Young adults' understanding and use of data: Insights for fostering secondary school students' data literacy," *Canadian Journal of Science, Mathematics and Technology Education*, vol. 18, pp. 330–341, 2018.

[6] J. Vanhoof, G. Verhaeghe, P. Van Petegem, and M. Valcke, "Improving data literacy in schools: Lessons from the school feedback project," *Data-based Decision Making in Education: Challenges and Opportunities*, pp. 113–134, 2013.

[7] J. Henderson and M. Corry, "Data literacy training and use for educational professionals," *Journal of Research in Innovative Teaching & Learning*, vol. 14, no. 2, pp. 232–244, 2021.

[8] B. Cowie and B. Cooper, "Exploring the challenge of developing student teacher data literacy," *Developing Teachers' Assessment Capacity*, pp. 27–43, 2019.

[9] N. Liliarti and H. Kuswanto, "Improving the competence of diagrammatic and argumentative representation in physics through android-based mobile learning application," *International Journal of Instruction*, vol. 11, no. 3, pp. 106–122, Jul. 2018. doi: 10.12973/iji.2018.1138a

[10] V. Ruf, A. Horrer, M. Berndt *et al*., "A literature review comparing experts' and non-experts' visual processing of graphs during problem-solving and learning," *Education Sciences*, vol. 13, no. 2, 2023. doi: 10.3390/educsci13020216

[11] W. Hidayatulloh, H. Kuswanto, P. H. Santoso, E. Susilowati, and Z. Hidayatullah, "Exploring students' misconception in the frame of graphic and figural representation on projectile motion regarding to the COVID-19 constraints," *JIPF (Jurnal Ilmu Pendidikan Fisika)*, vol. 6, no. 3, pp. 243–253, 2021.

[12] A. Susac, A. Bubic, P. Martinjak, M. Planinic, and M. Palmovic, "Graphical representations of data improve student understanding of measurement and uncertainty: An eye-tracking study," *Phys. Rev. Phys. Educ. Res.*, vol. 13, no. 2, 20125, 2017.

[13] D. T. Kurniawan, A. Suhandi, I. Kaniawati, and D. Rusdiana, "The analysis of learning obstacle and students learning motivation of prospective math teachers in basic physics class," *Journal of Physics: Conference Series*, 2017. doi: 10.1088/1742-6596/812/1/012026

[14] A. Stefanel, "Graph in physics education: from representation to conceptual understanding," *Mathematics in Physics Education*, 2019, pp. 195–231. doi: 10.1007/978-3-030-04627-9_9

[15] M. Satriawan, R. Rosmiati, W. Widia, F. Sarnita, L. Suswati, M. Subhan, and F. Fatimah, "Physics learning based contextual problems to enhance students' creative thinking skills in fluid topic," *Journal of Physics: Conference Series*, 22036, 2020.

[16] A. D. Rahmat, H. Kuswanto, I. Wilujeng, and E. Pratidhina, "Improve critical thinking skills using traditional musical instruments in science learning," *International Journal of Evaluation and Research in Education*, vol. 12, no. 4, pp. 2165–2175, 2023. doi: 10.11591/ijere.v12i4.25753

[17] L. B. Anthony, "The integration of ethno physics into school curriculum for skill acquisition among secondary school students in Nigeria," *International Journal of Innovative Research and Advanced Studies (IJIRAS)*, vol. 4, no. 8, pp. 62–65, 2017.

[18] M. Fidan and M. Tuncel, "Integrating augmented reality into problem based learning: The effects on learning achievement and attitude in physics education," *Comput. Educ.*, vol. 142, Dec. 2019. doi: 10.1016/j.compedu.2019.103635

[19] R. Sari, R. Perdana, Riwayani, Jumadi, I. Wilujeng, and H. Kuswanto, "The implementation of problem-based learning model with online simulation to enhance the student's analytical thinking skill in learning physics," *Journal of Physics: Conference Series*, 2019. doi: 10.1088/1742-6596/1233/1/012030

[20] D. U. Rahmawati, I. Wilujeng, J. Jumadi, H. Kuswanto, N. F. Sulaeman, and D. P. Astuti, "Problem based learning E-handout: improving students' mathematical representation and self efficacy," *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, vol. 9, no. 1, pp. 41–50, Apr. 2020. doi: 10.24042/jipfalbiruni.v9i1.4607

[21] M. C. Manyilizu, "Effectiveness of virtual laboratory vs. paper-based experiences to the hands-on chemistry practical in Tanzanian secondary schools," *Educ. Inf. Technol. (Dordr)*, vol. 28, no. 5, pp. 4831–4848, May 2023. doi: 10.1007/s10639-022-11327-7

[22] D. Rahmawati, A. Rusilowati, and W. Hardyanto, "The effect of practicum activities on improving data literacy for high school students physics communication," *Physics Communication*, vol. 5, no. 1, pp. 12–17, 2021. http://journal.unnes.ac.id/nju/index.php/pc

[23] N. Sudlow-Naggie, *The Effects of Virtual Laboratory Activities on Science Learning*, 2020.

[24] S. Chen, "The view of scientific inquiry conveyed by simulation-based virtual laboratories," *Comput. Educ.*, vol. 55, no. 3, pp. 1123–1130, Nov. 2010. doi: 10.1016/j.compedu.2010.05.009

[25] G. Gunawan, N. Nisrina, N. M. Y. Suranti, L. Herayanti, and R. Rahmatiah, "Virtual laboratory to improve students' conceptual understanding in physics learning," *Journal of Physics: Conference Series*, 2018. doi: 10.1088/1742-6596/1108/1/012049

[26] O. Falode, "Pre-service teachers' perceived ease of use, perceived usefulness, attitude and intentions towards virtual laboratory package utilization in teaching and learning of physics," *Malaysian Online Journal of Educational Technology*, vol. 6, no. 3, pp. 63–72, 2018. doi: 10.17220/mojet.2018.03.005

[27] A. R. Aththibby, H. Kuswanto, and Mundilarto, "Video-based mobile experiment activities for student creativity during the COVID-19 pandemic," 2023, 020013. doi: 10.1063/5.0115075

[28] D. Bogusevschi, C. Muntean, and G. M. Muntean, "Teaching and learning physics using 3D virtual learning environment: A case study of combined virtual reality and virtual laboratory in secondary school," *Journal of Computers in Mathematics and Science Teaching*, vol. 39, no. 1, pp. 5–18, 2020.

[29] R. G. Rahmawati, I. Wilujeng, and A. U. Kamila, "The effectiveness of stem-based student worksheets to improve students' data literacy," in *Proc. the 6th International Seminar on Science Education (ISSE 2020)*, 2021.

[30] C. Ridsdale, J. Rothwell, M. Smit *et al*., "Strategies and best practices for data literacy education knowledge synthesis report key messages," Knowledge synthesis report, 20215.

[31] M. A. Pratama, Supahar, D. P. Lestari, W. K. Sari, T. S. Y. Putri, and V. A. K. Adiatmah, "Data literacy assessment instrument for preparing 21 Cs literacy: Preliminary study," *Journal of Physics: Conference Series*, 2020. doi: 10.1088/1742-6596/1440/1/012085

[32] A. Ambarwati, Sarwanto, and Sukarmin, "The profile of students' data literacy at SMA Negeri 1 Karanganyar," *Journal of Physics: Conference Series*, 2020. doi: 10.1088/1742-6596/1511/1/012028

[33] A. S. Adam, S. Anggrayni, A. Kholiq, N. P. Putri, and N. Suprapto, "Analysis of graphical representation among freshmen in undergraduate physics laboratory," *Journal of Physics: Conference Series*, 2018. doi: 10.1088/1742-6596/997/1/012020

[34] I. S. Saldikov, V. V. Afanasyev, E. F. Kryuchkov, V. I. Petrov, M. Y. Ternovykh, and G. V. Tikhomirov, "Virtual labs on unique experimental equipment," in *Proc. the International Conference on Physics of Reactors*, 2014. doi: 10.1016/j.sbspro.2014.03.192

[35] W. Wibawanto, *Virtual Laboratory of Physics Simulation Concepts and Development (in Indonesian)*, Wandah Wibawanto, 2020.

[36] Herlinah and Musliadi, *Android Application Programming with Android Studio, Photoshop, and Audition (in Indonesian)*, Elex Media Komputindo, 2019.

[37] Sudarmin, R. Febu, M. Nuswowati, and W. Sumarni, "Development of ethnoscience approach in the module theme substance additives to improve the cognitive learning outcome and student's entrepreneurship," *Journal of Physics: Conference Series*, 2017. doi: 10.1088/1742-6596/824/1/012024

[38] N. Hasanah, Sahyar Sahyar, and Derlina Derlina, "Ethnophysical integration in cooperative learning based on Batak culture to improve Generic Skills of Science (GSS) and student teamwork," *Jurnal Pendidikan Fisika*, vol. 10, no. 1, pp. 67–71, 2021.

[39] F. Virijai and A. Asrizal, "Development of ethnophysics-based augmented reality assisted digital teaching material for 21st century learning," *Jurnal Penelitian Pendidikan IPA*, vol. 9, no. 11, pp. 9200–9209, Nov. 2023. doi: 10.29303/jppipa.v9i12.4583

[40] E. Chongo and G. Trivikram Baliga, "Effect of ethnophysics-based instruction on students' academic performance and attitude towards density, forces and heat transfer in college physics: A case of mufulira college of education," *Journal of Education and Practice*, vol. 10, 2019.

[41] S. A. Dunham, *Archipelago Iron Warriors: Anthropological Study of Traditional Blacksmiths in Indonesia (in Indonesian)*, PT Mizan Publika, 2008.

[42] R. R. Hake, "Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses," *Am. J. Phys*., vol. 66, no. 1, pp. 64–67, 1998.

[43] G. Hamed and A. Aljanazrah, "The effectiveness if using virtual experiments on students' learning in the general physics lab," *Journal of Information Technology Education: Research*, 2020.

[44] H. Hermansyah, G. Gunawan, A. Harjono, and R. Adawiyah, "Guided inquiry model with virtual labs to improve students' understanding on heat concept," *Journal of Physics: Conference Series*, 012116, 2019.

[45] A. Maghfiroh and H. Kuswanto, "Benthik android physics comic effectiveness for vector representation and crtitical thinking students' improvement," *International Journal of Instruction*, vol. 15, no. 2, pp. 623–640, 2022. doi: 10.29333/iji.2022.15234a

[46] M. Bond and S. Bedenlier, "Facilitating student engagement through educational technology: towards a conceptual framework," *Journal of Interactive Media in Education*, vol. 2019, no. 1, 2019.

[47] A. D. Rahmat, H. Kuswanto, and I. Wilujeng, "Integrating technology into science learning in junior high school: perspective of teachers," *Journal of Research in Science Education*, vol. 9, no. 5, pp. 2391–2396, 2023. doi: 10.29303/jppipa.v9i5.2922

[48] Sudirman, Mellawaty, R. P. Yaniwati, and R. Indrawan, "Integrating local wisdom forms in augmented reality application: Impact attitudes, motivations and understanding of geometry of pre-service mathematics teachers'," *International Journal of Interactive Mobile Technologies*, vol. 14, no. 11, pp. 91–106, 2020. doi: 10.3991/ijim.v14i11.12183

[49] N. R. Herga, M. I. Grmek, and D. Dinevski, "Virtual laboratory as an element of visualization when teaching chemical contents in science class," *Turkish Online Journal of Educational Technology-TOJET*, vol. 13, no. 4, pp. 157–165, 2014.

[50] V. Potkonjak, M. Gardner, V. Callaghan *et al*., "Virtual laboratories for education in science, technology, and engineering: A review," *Comput. Educ*., vol. 95, pp. 309–327, 2016.

[51] U. Sari, H. M. Pektaş, H. Çelik, and T. Kirindi, "The effects of virtual and computer based real laboratory applications on the attitude, motivation and graphic interpretation skills of university students," *International Journal of Innovation in Science and Mathematics Education*, vol. 27, no. 1, 2019.

[52] A. Ranjan, "Effect of virtual laboratory on development of concepts and skills in physics," *International Journal of Technical Research & Science*, vol. 2, no. 1, pp. 15–21, 2017.

[53] J. M. Coleman, E. M. McTigue, and L. B. Smolkin, "Elementary teachers' use of graphical representations in science teaching," *J. Sci. Teacher Educ*., vol. 22, no. 7, pp. 613–643, 2011. doi: 10.1007/s10972-010-9204-1

[54] M. Khine and L. Yang, "Descriptive analysis of the graphic representations of science textbooks," *European Journal of STEM Education*, vol. 2, no. 3, pp. 1–15, 2017. doi: 10.20897/ejsteme/81285

[55] E. Widodo, "The effect of virtual laboratory application of problem-based learning model to improve science literacy and problem-solving skills," in *Proc. 7th International Conference on Research, Implementation, and Education of Mathematics and Sciences (ICRIEMS 2020)*, 2021, pp. 633–640.

[56] D. P. Lestari, Supahar, Paidi, Suwarjo, and Herianto, "Effect of science virtual laboratory combination with demonstration methods on lower-secondary school students' scientific literacy ability in a science course," *Educ. Inf. Technol. (Dordr)*, pp. 1–23, 2023.

[57] R. D. Handayani, I. Wilujeng, and Z. K. Prasetyo, "Elaborating Indigenous knowledge in the science curriculum for the cultural sustainability," *Journal of Teacher Education for Sustainability*, vol. 20, no. 2, pp. 74–88, 2018.

[58] M. Congretel and F. Pinton, "Local knowledge, know - how and knowledge mobilized in a globalized world: A new approach of indigenous local ecological knowledge," *People and Nature*, vol. 2, no. 3, pp. 527–543, 2020.

[59] S. K. Puri, "Integrating scientific with indigenous knowledge: Constructing knowledge alliances for land management in India," *MIS Quarterly*, pp. 355–379, 2007.

[60] A. D. Rahmat, H. Kuswanto, and I. Wilujeng, "Integrating pentatonic angklung into physics experiment to identify multiple representation skills in junior high school," *Jurnal Ilmiah Pendidikan Fisika Al-Biruni*, vol. 12, no. 1, pp. 77–87, 2023. doi: 10.24042/jipfalbiruni.v12i1.15984

[61] A. Alfianti, H. Kuswanto, A. D. Rahmat, and R. Nurdiyanto, "Development of DICTY-AR integrated local wisdom to improve multiple representation and problem-solving skills," *International Journal of Information and Education Technology*, vol. 13, no. 9, pp. 1383–1390, 2023. doi: 10.18178/ijiet.2023.13.9.1941

[62] F. Kurnianto, A. Datiatur Rahmat, and H. Kuswanto, "The effect of augmented reality integrated traditional games Nglarak Blarak to improve critical thinking and graphical representation skills," *Pegem Journal of Education and Instruction*, vol. 14, no. 2, pp. 340–346, 2024. doi: 10.47750/pegegog.14.02.41

[63] A. D. Rahmat, I. Wilujeng, H. Kuswanto, A. N. Mat Daud, and D. Saepuzaman, "Development worksheet integrated PhET simulation to improve critical thinking skills in junior high school," *Jurnal Pendidikan Sains Indonesia*, vol. 12, no. 1, pp. 111–123, 2024. doi: 10.24815/jpsi.v12i1.34742

[64] Y. Daineko, V. Dmitriyev, and M. Ipalakova, "Using virtual laboratories in teaching natural sciences: An example of physics courses in university," *Computer Applications in Engineering Education*, vol. 25, no. 1, pp. 39–47, 2017.

[65] M. Abou Faour and Z. Ayoubi, "The effect of using virtual laboratory on grade 10 students' conceptual understanding and their attitudes towards physics," *J. Educ. Environ. Sci. Health*, vol. 4, no. 1, pp. 54–68, 2017.

[66] A. Datiatur Rahmat, I. Wilujeng, and H. Kuswanto, "The effect of mobile learning integrated traditional games Egrang to improve multiple representation skills," *Article in Journal of Science Learning*, vol. 6, no. 4, pp. 435–441, 2023. doi: 10.17509/jsl.v6i4.57961

[67] Y.-C. Chiang and S.-C. Liu, "The effects of extended reality technologies in STEM education on students' learning response and performance," *Journal of Baltic Science Education*, vol. 22, no. 4, pp. 568–578, 2023.

[68] M. R. D. Saputra and H. Kuswanto, "The effectiveness of Physics Mobile Learning (PML) with HomboBatu theme to improve the ability of diagram representation and critical thinking of senior high school

students," *International Journal of Instruction*, vol. 12, no. 2, pp. 471–490, Apr. 2019. doi: 10.29333/iji.2019.12230a

[69] E. Kartika, M. Enjelina Suban, and Z. Ummul Arafah, "Students' data literacy ability in physics using the physics e-module integrated with the values of Pancasila during the COVID-19," in *Proc. 6th International Seminar on Science Education (ISSE 2020)*, 2021.