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Strengthening Physics Scientific Literacy in the Millennial Generation through the Blended Learning Model

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ABSTRACT
This study aims to analyze the improvement of scientific literacy in millennial students during physics learning through the implementation of the blended learning model. A quasi-experimental design with a nonequivalent control group was used. The experimental class applied the blended learning model, while the control class used conventional learning methods. Data were collected through scientific literacy tests administered as pretests and posttests, which were then analyzed using descriptive statistics and t-tests to examine the significance of differences between the two groups. The results indicate a significant difference in posttest scientific literacy scores between the experimental and control classes. The average posttest score in the experimental class was higher than that of the control class, suggesting that the blended learning model was more effective in enhancing students' scientific literacy. The t-test yielded a t-count of 2.053, which was greater than the t-table value of 1.996, with a significance level of 0.05. Based on these findings, it can be concluded that the blended learning model is more effective in improving the scientific literacy of millennial students, particularly in physics education. Future research could explore further optimization of blended learning implementation to enhance various aspects of scientific literacy.

Keywords: *Blended Learning; Conventional Learning; Millennial Students; Physics Education; Scientific Literacy.*

INTRODUCTION

The rapid development of the 4.0 industrial revolution in science and technology has highlighted the need for effective educational strategies. Millennial students, aware of the demands of IR 4.0, are motivated to develop digital literacy for both academic and professional success (Rusdinal & Afriansyah, 2023). To engage this generation, transitioning from traditional to blended learning models, which combine online and face-to-face instruction, is essential (Şentürk, 2020). These models align with the growing

emphasis on STEM, critical thinking, and digital literacy in education (Sekiyama, 2020; Basri, 2024). At SMAN 1 Sendana in West Sulawesi, the shift to online platforms like Google Classroom and WhatsApp has become necessary due to pandemic restrictions, further emphasizing the need for innovative learning models to improve students' scientific literacy.

Millennial students, aged between 15 and 34 years, are expected to possess science literacy, a key competency in the 4.0 industrial revolution and the 21st century (MacDonald, 2021). To foster this, approaches such as STEM e-modules aligned with Sustainable Development Goals (SDGs) and the integration of cultural or religious values have proven effective in enhancing science literacy and related attitudes (Aswirna et al., 2022; Yuningsih et al., 2022). This generation, driven by innovation, thrives in an environment that heavily relies on technology to drive change across various aspects of their lives (Chama et al., 2021; Yu, 2022).

Despite efforts to improve science literacy, Indonesian millennial students show low achievement. For instance, at SMA Negeri 1 Sendana, only 4 out of 30 students could answer a science literacy question related to interpreting data and evidence, indicating a significant gap in their science literacy (Sukarno & El Widdah, 2020). The shift to online learning during the pandemic, often implemented without an effective learning model, has further exacerbated this issue. Research by Kuhfeld et al. (2020) and Uğraş et al. (2023) highlights how this shift has led to significant learning loss, especially in science subjects. As a result, students have experienced a decline in both scientific abilities and achievement, which has been further compounded by inadequate online learning support (Aurini & Davies, 2021).

The low science literacy of Indonesian students has consistently been reflected in international assessments, such as PISA. In 2012, Indonesia ranked 64th out of 65 countries with a score of 382, which marked a decline from previous years (Sutrisna & Anhar, 2020). Although there was a slight improvement in 2015, with a score of 403, the 2018 results showed a significant drop back to 396, far below the national target and the OECD average (OECD, 2023; Cahyani & Setiawan, 2024). This trend highlights the ongoing challenge of improving science literacy among Indonesian students.

The COVID-19 pandemic has significantly disrupted physics education, causing a decline in scientific literacy and learning loss due to ineffective online learning models (Di Pietro, 2023). Studies in Indonesia highlight that many students, especially in physics, are only able to demonstrate basic knowledge and struggle with data interpretation (Melinda et al., 2021). This suggests a pressing need for more effective learning models, such as blended learning, which combine face-to-face and online instruction, to engage students better and improve scientific literacy.

It is well known that physics is a science that is closely related to life, the material has a number of concepts, formulas that must really be understood, to the need for face-to-face contact in the learning process (Boma et al., 2024). However, students in the past were different from today's students who were used to technology (gadgets/smartphones) (Arlim et al., 2023). Therefore, to increase the science literacy of millennial students in urgent physics learning, it is necessary to use the right way and be supported by technology as a support for the demands of 21st century learning without eliminating face-to-face (conventional) learning (Putri dan Ramli, 2023). According to Lestari (2020), technology in learning is an important element that must be

presented in activities in schools in learning knowledge and learning and teaching processes to improve the science literacy of millennial students. This is in line with the Government's program in the use of learning principles outlined in Permendikbudristek No. 16 of 2022 concerning Process Standards in Early Childhood Education, Primary Education and Secondary Education that "the use of information and communication technology to improve learning efficiency and effectiveness".

In improving science literacy, educators are challenged to integrate learning models and information technology advances to keep pace with the diverse learning styles of millennial students. Thus, a learning model that can be applied to strengthen the science literacy of millennial students in physics learning is a blended learning model. Blended learning is a conceptual model based on the perspective of the learning setting, in which learning can be carried out synchronously and asynchronously using various web-based technologies, e-learning and multimedia technologies, such as video streaming, virtual classes, online text animations combined with traditional forms of classroom training and individual training (Akıllı & Kutur, 2023; Sharon & Baram-Tsabari, 2020).

Strengthened by previous research using a blended learning model conducted by Lestari (2020), the results of his research show that the average value of millennial students' science literacy skills is in the good category through the application of the blended learning model. Research that also uses a blended learning model has been conducted by Kade et al. (2019). The results of the study show that the blended learning model has an effect on increasing the science literacy of millennial students.

Based on the description of the above problem and the solution proposed by the researcher, the researcher is interested in studying "Strengthening Science Literacy of the Millennial Generation in the 4.0 Era in Physics Learning Through Blended Learning Model" with the aim of finding out whether there is a significant science literacy of millennial students in physics learning between classes that use the blended learning model and classes that use conventional learning. The achievement of science literacy will be measured using science literacy indicators in the competency aspect.

METHODS

Study Location, Participants, and Sampling

This research was carried out in the odd semester of the 2024/2025 school year with a population of 104 millennial students in class XI Science with the sample used in the study being all millennial students in class XI Science 2 SMA Negeri 1 Sendana as an experimental class and all students in grade XI Science 3 SMA Negeri 1 Sendana as a control class at SMA Negeri 1 Sendana which is located at Jln. Sejahtera No. 20 Somba Mosso Village, Sendana District, Majene Regency, West Sulawesi Province.

Research Design

This study employs a quantitative approach with a quasi-experimental design and a nonequivalent control group design (Sugiyono, 2019). The population of this study consisted of 104 millennial students from class XI Science at SMA Negeri 1 Sendana during the 2024/2025 academic year. From this population, the sample included all students from class XI Science 2 (36 students) as the experimental group and all students

from class XI Science 3 (33 students) as the control group, selected using purposive sampling. The experimental group received treatment using a blended learning model, while the control group continued with the traditional online learning model. This design allows for comparing the effectiveness of blended learning in improving science literacy, while accounting for the non-randomized nature of the sampling.

Research Procedure

This research was carried out in three stages:

1. Preparation Stage

In this stage, the researchers conducted preliminary observations at SMA Negeri 1 Sendana, consulted with physics teachers about the conditions of millennial students, and determined the research needs. This included preparing the instruments and lesson plans, validating the instrument items, and obtaining research permits. The permits included letters from the University of West Sulawesi, the Majene district government, and SMA Negeri 1 Sendana. Additionally, informed consent was obtained in writing from all participating teachers and students.

2. **Implementation Stage**

The second stage involved administering a pretest to the two samples: the experimental class (XI Science 2) and the control class (XI Science 3). These groups were selected using purposive sampling based on recommendations from the physics teachers at SMA Negeri 1 Sendana.

a. **Experimental Class:** The students in the experimental class engaged in blended learning, which consisted of three main components:
   - Information search, conducted asynchronously and independently through the Google Classroom group.
   - Information acquisition, carried out asynchronously in a collaborative manner with the provision of LKPD (Student Worksheet) in the Google Classroom group.
   - Knowledge reconstruction, which was done asynchronously and independently by uploading the results of the LKPD discussion through Google Classroom. Additionally, synchronous virtual sessions were held via Google Meet for teacher evaluation and material conclusion.

b. **Control Class:** The students in the control class participated in conventional online learning, which involved two components:
   - Material presentation, conducted through Google Meet.
   - Independent assignments, which were given and assessed through Google Classroom.

   After the learning activities, a posttest was conducted for both the experimental and control classes.

3. **Final Stage**

In the final stage, the data collected from the pretest and posttest in both classes were processed and analyzed to assess the effectiveness of the blended learning model in improving science literacy.

Science Literacy Data Collection

Data on science literacy were collected using a test instrument developed from the "Development of Assessment Instruments to Measure Scientific Skills of Thermal Material Literacy" (Sartika et al., 2023). The instrument was designed to meet high validity standards and was based on three key competency aspects: explaining scientific phenomena, evaluating and designing scientific investigations, and interpreting data and evidence scientifically. These competencies were assessed through a series of multiple-choice questions, ensuring that the test effectively measured the relevant aspects of science literacy.

Data Analysis

The data collected in this study were analyzed using both descriptive and inferential statistical techniques. Descriptive statistics were employed to summarize the research findings, focusing on measures such as averages, standard deviations, and score percentages. This helped to provide a clear understanding of the overall performance and trends within the sample. Additionally, inferential statistics were used to generalize the results from the sample to the larger population. This included conducting normality tests using the chi-squared formula, homogeneity tests with the F-test, and hypothesis testing with T-tests (pooled variants) to assess the significance of the findings and draw conclusions based on the data (Harris, 2016; Guerro, 2018; Hui, 2018; Al-Benna et al., 2010).

As for the categorization of science literacy achievements of millennial students, table 1 is used below:

Table 1. Category of Percentage of Students' Science Literacy Test

Percentage	Description
86 – 100%	Excellent
76 – 85%	Good
60 – 75%	Sufficient
55 – 59%	Low
< 54%	Very Low

RESULTS

The results of the science literacy assessment for millennial students in physics learning are presented in this section. The analysis compares the performance of students in two different learning environments: the experimental class, which implemented the blended learning model, and the control class, which followed a conventional learning approach. The data from both pretest and posttest assessments are presented below, providing insights into the impact of the blended learning model on students' scientific literacy.

Table 2 shows the descriptive statistics of science literacy scores for both the experimental and control classes. The results indicate that the experimental class, which employed the blended learning model, showed a significant increase in posttest scores compared to the control class. This suggests that blended learning positively influenced students' ability to engage with and understand scientific concepts. Table 3 offers a

deeper look into the competency aspects of science literacy, where the experimental class consistently outperformed the control class. Additionally, the t-test results in Table 4 confirm that the difference in posttest scores between the two classes is statistically significant, further supporting the effectiveness of blended learning in enhancing scientific literacy.

Table 2. Descriptive Results of Science Literacy of Millennial Students in Physics Learning Control Experiment

Score Assessment	Experiment		Control	
	Pretest	*Posttest*	*Pretest*	*Posttest*
Maximum	13	19	12	15
Minimum	2	9	1	7
Ideal	20	20	20	20
Mean	7,22	14,69	6,39	11,06
SD	2,520	3,590	2,478	2,496

As shown in Table 2, the posttest results for the experimental class indicate a significant improvement compared to the control class. This is supported by looking at the per-indicator aspects of competency in table 3 below.

Table 3. Category Results of Each Science Literacy Indicator Competency Aspects of Millennial Students

		Competency Indicators		
		(1)	(2)	(3)
Experiment	Pretest	36%	31%	38%
	Category	Very Low	Very Low	Very Low
	Posttest	78%	68%	68%
	Category	Good	Sufficient	Sufficient
Control	Pretest	36%	27%	29%
	Category	Very Low	Very Low	Very Low
	Posttest	63%	36%	54%
	Category	Sufficient	Very Low	Very Low

Based on table 3, there is a clear difference in the posttest science literacy results, with the experimental class achieving the 'sufficient' category, while the control class remains in the 'insufficient' category. This further demonstrates that the blended learning model is more effective in enhancing the science literacy of millennial students

Table 4. Results of the Science Literacy Posttest T Test in Physics Learning between the Experimental Class and the Control Class

Data	t count	Dk	t table	Information
Science literacy of millennial students in physics learning between experimental classes and control classes	2,053	67	1,996	There are significant differences

The t-test results presented in Table 4 show that the t count value of 2.053 is greater than the t table value of 1.996, indicating a statistically significant difference in science literacy scores between the experimental and control classes. This supports the

conclusion that the blended learning model significantly improves the science literacy of millennial students in physics learning compared to conventional learning.

DISCUSSION

Based on the results of the study using descriptive statistical analysis and inferential statistics, an overview of the participants' science literacy achievements educate millennials when using learning models that differ from the two classes. In this study, two learning models were used, namely blended the learning model in the experimental classroom and the direct learning model in the classroom control. Comparative data of pretest and posttest science literacy in both classes is further elaborated in the following paragraphs.

It is known that the data on the results of the science literacy pretest of millennial students in the classroom experiments are classified as very low. This can be seen from the achievement of the score The average pretest was 7.22 which is quite far from the ideal score of 20. This data is also supported by a categorization diagram that 97% of millennial students are in the "less than once" category. If the data is reviewed in terms of per- Science literacy indicators of competency aspects consisting of: (1) explaining phenomena scientifically; (2) evaluate and design scientific investigations; and (3) interpret data and evidence scientifically, successively obtained The percentages of 36%, 31%, and 38% remain in the "less than once" category. Not However, the data on the diagram of the pretest results of millennial students obtained a score of the highest score of 13 achieved by only one person, while the lowest score as much as 2 is achieved by two people. From the teaching experience that was carried out by researchers during PLP in physics learning at SMA Negeri 1 Sendana Where millennial students are only used to memorizing formulas, but still Lack of skills in using the knowledge they have. For example when asked to communicate and relate various physics topics, especially in the application of concepts with the surrounding scientific phenomena, it turns out that They have not been able to answer it. From the above phenomenon, it is indicated that Millennial students are less literal (Soroya, et al., 2022).

In line with the results of the pretest in the experimental class, in the control class, the results were also obtained that the science literacy pretest data was still very low. The cause of this low pretest is also the same as previously explained, namely from the achievement of an average pretest score of only 6.39, which is quite far from the ideal score of 20. In addition, the data is supported by a categorization diagram where 97% of millennial students are in the "less than once" category. The data is also in harmony when looking at the per-indicators of science literacy, the competency aspects, including indicators (1) explaining the phenomenon scientifically were obtained by 36%. However, for indicators (2) evaluating and designing scientific investigations; and indicator (3) interpreting data and evidence scientifically turned out to be lower than in the experimental class of 27% and 29% in the "very less" category. In addition, the data of the pretest results of millennial students obtained the highest score of 12 which was only achieved by one person while the lowest score was 2 achieved by two people and one person was 1.

After being treated using a blended learning model, the data model of the science literacy posttest results of millennial students in the experimental class increased compared to the pretest results, which were quite sufficient. This data is seen from the

average posttest achievement of 14.69 which is quite close to the ideal score of 41, which is 20. Furthermore, the data is also supported by a categorization diagram that 61% of millennial students reach the "adequate" category. Similar things from the data in terms of per-indicators of science literacy and competency aspects, including: (1) explaining phenomena scientifically; (2) evaluate and design scientific investigations; and (3) interpret data and evidence scientifically, respectively obtained 78%, 68%, and 68% reaching the "adequate" category. Then, the data on the posttest result diagram of millennial students obtained the highest score of 19 achieved by one person while the lowest score was 9 achieved by one person.

In contrast to the posttest results in the experimental class, the data on the results of the science literacy posttest in the control class was very low even though there had been an increase in the achievement of an average posttest score of 11.06 which was quite close to the ideal score of 20. On the other hand, the data is supported by a categorization diagram which shows that 36% of millennial students are in the "sufficient" or "not enough" category and the rest are in the "less" category. If the data is viewed in terms of science literacy indicators, the competency aspect includes indicators (1) explaining the phenomenon scientifically, where the results are quite an increase of 63%. On the other hand, for indicators (2) evaluating and investigating scientific designs; and indicator (3) interpreting data and evidence scientifically, respectively by 36% and 54%, which ironically is much lower than the experimental class, which is included in the "less than once" category. Finally, from the data of the posttest results diagram of millennial students, the highest score of 15 was achieved by one person, while the lowest score of 7 was achieved by one person. Therefore, by referring to the data presented earlier, it can be concluded that there is a difference in the results of the science literacy posttest between the two classes.

From the data on the difference in science literacy posttest results in the two classes, it is proven that the blended learning model can strengthen the science literacy of millennial students. This can be seen from the value of the posttest compared to the pretest in the experimental class which is more effective in corroborating than in the control class that uses conventional learning. In addition, the blended learning model syntax also has suitability for each science literacy indicator in terms of competence. Syntax (1) information search, namely millennial students are given perceptual videos in the form of problems or concept questions related to phenomena so that they are trained to communicate and relate physics concepts with scientific phenomena around them. Then, the syntax (2) of information acquisition, namely millennial students are given science literacy-oriented LKPD which is carried out online so that they are trained to answer questions about indicators of competency aspects consisting of explaining phenomena scientifically, evaluating and designing scientific investigations, and interpreting data and evidence scientifically. Furthermore, syntax (3) reconstructs knowledge even though it is not related to science literacy indicators. However, the syntax has a positive impact because there is an evaluation of learning and material conclusions with millennial students which is carried out through face to face (face-to-face) using the Google Meet application, so that interaction or reciprocal relationships are established between educators and millennial students. This is in accordance with the advantages of the blended learning model, which is to increase communication activities between educators and millennial students, especially in online interactions.

The above statement is also strengthened from the results of inferential statistical analysis using a two-party T test and supported by previous studies. As stated by Lestari (2020) in his research results, the average value of the science literacy ability of millennial students is in the good category through the application of the blended learning model. Kade et al. (2019) in their research also stated that the blended learning model has an effect on improving the science literacy of millennial students. In connection with the overview of the research results to support educators in using the blended learning model, it is recommended that school principals encourage and facilitate teachers. Likewise, the school supervisor of the SMA Negeri 1 Sendana Education Unit can provide guidance and motivation for educators, not only educators of physics subjects but all subject educators about learning models that are effectively used in their areas and are able to strengthen the science literacy of millennial students, especially during the new normal of the Covid-19 pandemic. Also most importantly, millennial students are advised to be more active in learning so that the implementation of the blended learning model can run well.

This research has limitations in terms of the implementation of the blended learning model which is only focused on the competency aspect in students' science literacy, without exploring other aspects such as context and knowledge. In addition, the implementation of research was carried out during the new normal of the COVID-19 pandemic, which presented a number of obstacles and obstacles, especially in the implementation of online learning. This condition has the potential to affect the optimization of the application of the learning model and the results obtained. Therefore, caution is needed in generalizing these findings, and researchers are then expected to consider similar conditions and expand the research variables so that the results obtained are more comprehensive and applicable.

CONCLUSION

The results of this study indicate a significant improvement in the science literacy of millennial students in physics learning using the blended learning model. The statistical analysis, as shown by the t-test results, confirms that the posttest scores of the experimental class, which applied blended learning, are significantly higher than those of the control class, which used conventional learning methods. The t-value of 2.053 is greater than the t-table value of 1.996, indicating a statistically significant difference in science literacy between the two groups.

These findings highlight the effectiveness of blended learning in enhancing students' ability to understand and apply scientific concepts. The experimental class demonstrated notable improvement across key aspects of scientific literacy, such as explaining phenomena scientifically, evaluating and designing scientific investigations, and interpreting data and evidence.

Based on these results, it can be concluded that blended learning is a more effective approach for strengthening the scientific literacy of millennial students, particularly in physics education. Future research can explore further improvements in the implementation of blended learning and its impact on different aspects of science literacy.

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