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Development Of Stoichiometry Learning Materials Based On PBL Integrated With SDGs Used By Nearpod To Improve Learning Outcomes and Environmental Literacy

Nurul Unsa, Sri Haryani, Nuni Widiarti

Universitas Negeri Semarang

Keywords

Stoichiometry , PBL, SDGs, Nearpod, Learning Outcomes , Environment Literacy

Abstract

This research aims to develop chemistry teaching materials on stoichiometry material based on Problem Based Learning (PBL), integrated with Sustainable Development Goals (SDGs) issues, and supported by Nearpod digital technology. The background of this research is the low learning outcomes of students caused by inadequate teaching materials which influence the lack of active involvement of students in the learning process, as well as the need to improve students' environmental literacy. The research uses the 4-D development model (Define, Design, Develop, Disseminate). The research subjects consisted of class X students of MAN 1 Jepara who were divided into a control class and an experimental class. Data were collected through observation, interviews, expert validation, implementation tests, effectiveness tests, and student and teacher response questionnaires. The validation results by material experts show that the teaching materials are declared very feasible with a validity value of the Aiken's V index of 0.898 (high category), reliability of material experts (Percentage of Agreement): 98.87% (reliable), and percentage of feasibility of material experts: 92.36% (very feasible). The validation results by media experts showed that the teaching materials were declared very feasible with a validity value of the Aiken's V index of 0.939 (high category), reliability of media experts (Percentage of Agreement): 97.6% (reliable), percentage of feasibility of media experts: 95.45% (very feasible). The effectiveness test showed an increase in the learning outcomes of the experimental class (N-Gain = 0.45) and the environmental literacy of the experimental class (N-Gain = 0.34) in the moderate category and higher than the control class. The results of the Pearson correlation test showed a significant positive relationship between learning outcomes and environmental literacy ($r = 0.405$, $p < 0.01$). Thus, this teaching material is effective in improving students' learning outcomes and environmental literacy.

*Correspondence Address:
E-mail:
unsanilia@students.unnes.ac.id

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INTRODUCTION

Environmental problems have increased significantly in quantity and quality and threaten human existence on earth (Shukla & Tiwari, 2021) . This problem needs serious attention from all parties, including the world of education. Environmental education related to climate change is a very important strategy in helping communities understand and deal ith its impacts (Kementerian PPN/Bappenas, 2024). Based on the results of mapping and data analysis, it shows that environmental literacy is an important component in achieving 21st century learning (Mitarlis et al., 2017). By increasing environmental literacy, it is hoped that individuals can make wiser decisions, implement sustainable behavior, and play an active role in solving environmental problems (Ariyatun et al., 2024).

Environmental protection is one of the pillars of the UN Sustainable Development Goals (SDGs) alongside economic development and social progress/justice (Leiserowitz et al., 2004). SDGs are an agreement between UN member states to ensure sustainable development throughout the world with the aim of eradicating poverty, protecting the planet, and ensuring a decent standard of living for all by 2030 (Widodo et al., 2023) . There are 17 Sustainable Development Goals (UN Assembly, 2015) agendas, one of which is quality education. Besides being one of the SDGs goals, quality education is also a means to achieve other SDG goals (Widodo et al., 2023). Efforts to develop quality and equitable education have been formulated by the government through the Indonesian Education Roadmap (PJPI) 2025-2045 as part of the implementation of the Golden Indonesia 2045 vision (Kementerian PPN/Bappenas, 2024).

One of the problems still faced by the world of education in Indonesia is the achievement of students in essential competencies and the quality of learning which is not yet optimal. Efforts to improve the quality of teaching and learning are part of the policy direction in the Indonesian Education Roadmap, including through the development of learning innovations by utilizing digital technology and the application of modern pedagogy (Kementerian PPN/Bappenas, 2024).

Sustainability values in the SDGs are increasingly recognized as an important aspect of education. This is to build an attitude of environmental care and social awareness among students (Zulfah et al., 2024). In order to foster sustainable values, education is needed that is specifically designed to instill knowledge, awareness and real action in students, known as Education for Sustainable Development (ESD). However, the current curriculum structure in Indonesia does not include ESD subjects, so it is necessary to integrate ESD into relevant subjects, including chemistry (Widodo et al., 2023; Zowada et al., 2022). The forms of implementation include including ESD values into the context of chemistry learning, integrating them into learning models or approaches, and developing ESD values through learning design and teaching materials (Murti & Hernani, 2023). Integrating ESD into the PBL model not only teaches students to solve problems but also to understand sustainable issues and develop an attitude of environmental care (Zulfah et al., 2024).

Problem Based Learning (PBL) model is a way of presenting learning materials by making problems the starting point for discussing problems to be analyzed and synthesized in an effort to find solutions or answers by students. Problems can be submitted or given by teachers to students, by students together with teachers, or by students themselves, which are then discussed and solutions sought as student learning activities. This learning model is one of the learning models of the Society 5.0 era (Badrus et al., 2021). The PBL model is in accordance with the philosophy of meaningful constructivism, and can link students' real-life experiences with the subject matter (Ramdoniati et al., 2018).

Chemistry is one of the subjects at the SMA/MA/Package C level. Based on various research results, the main problem in chemistry education is the difficulties faced by students in learning chemistry. This is because the characteristics of chemistry when viewed from the perspective of representation theory show that chemical phenomena involve three levels of representation, namely macroscopic, submicroscopic and symbolic levels (Farida, 2018).

Stoichiometry is a fundamental topic in chemistry lessons that requires conceptual understanding and problem-solving skills (Fuzi & Yahaya, 2024), so that many students experience difficulties with this material. This is proven by the results of the formative assessment on the Stoichiometry material at MAN 1 Jepara, which obtained low student scores. The same thing also happened to most of the MA in Jepara district. Based on the results of the questionnaire given to MA chemistry teachers in Jepara district, data was obtained that the students' achievement results on stoichiometry material were classified as low. Factors that influence the achievement of student learning outcomes include teaching materials and the learning models used. The main teaching materials in chemistry learning at MAN 1 Jepara are in the form of textbooks, whose number is insufficient for all students and the condition of the books is damaged. Meanwhile, in other MAs, the main teaching materials used are printed LKS which are sold freely. The learning models used by teachers generally do not stimulate motivation and active participation of students in the learning process. In addition to the problem of learning outcomes that need to be improved, students' environmental literacy also needs to be improved in order to achieve 21st century learning competencies.

Teaching materials are something used by teachers or students to facilitate the learning process (Kosasih, 2022). Chemistry teaching materials are a collection of chemistry materials based on the curriculum in force in an educational institution as a means to achieve the basic competencies that have been determined. One of the functions of chemistry teaching materials is to make learning more effective, interactive and focused, as well as a tool for evaluating learning (Aldian & Wahyudiati, 2023).

Digital devices, especially mobile phones, have become an inseparable part of people's lives, including in learning activities at school. This is supported by increasingly easy internet access, so that in its development, innovations in the development of digital-based teaching materials have emerged. Digital teaching materials are teaching materials that use digital devices, such as computers, smartphones, laptops and the like (Kosasih, 2022). This teaching material is in accordance with the characteristics of generation Z. According to Kusumaningtyas et al, (2020), students in generation Z prefer to communicate with images, icons and symbols rather than text, interacting in a complex way with media such as smartphones, televisions, laptops, desktops and iPods. Thus, what educators need to build is implementing student-centered learning, where digital technology becomes a learning infrastructure that is favored by Generation Z. Teachers play a greater role as mentors, guides and trainers with wisdom, knowledge and experience. Prismanata & Tinjung Sari (2022) also recommend the formulation of learning media with audiovisual, application, and website formats for Generation Z and Generation Alpha students reviewed from several aspects, such as learning psychology, learning styles, learning components, multimedia design principles, and visual principles.

Nearpod is a web-based application or online learning platform that is very interesting because it brings active interaction between educators and students. Nearpod has more functions than traditional PowerPoint media, including providing various ways for students to get information about learning materials while providing a variety of evaluation techniques and being able to provide academic reports for teachers at one time (Qi et al., 2021). The integrated PBL learning model of SDGs sustainability values applied through Nearpod interactive media is expected to create interactive and collaborative learning, a learning environment that is able to stimulate students, and increase students' motivation and active participation.

Based on the background explanation, it is necessary to conduct research related to the development of PBL-based Stoichiometry teaching materials that integrate SDGs sustainability values and are packaged in Nearpod interactive media. The difference between the developed teaching materials and the previously existing teaching materials for Stoichiometry is the integration of SDGs with the PBL model, as well as its packaging in the interactive Nearpod application. The importance of this research is to produce alternative teaching materials on Stoichiometry material which is expected to improve students' learning outcomes and environmental literacy.

METHODS

This type of research is research and development (R&D) using the 4-D model. The define stage is carried out through observation and interviews to find out the real needs in the field. The design stage includes the preparation of teaching materials based on PBL syntax and the integration of SDGs issues in five stoichiometry topics. This stage begins with the process of reviewing and integrating Stoichiometry material with contextual problems related to the SDGs, followed by selecting media and product formats. Development of teaching materials using computer programs, namely Microsoft Word 2019, Canva and the nearpod application. The development stage includes expert validation, implementation testing, and effectiveness testing. The dissemination stage is carried out through publication of research results in national or international journals.

The subjects of this study were students of MAN 1 Jepara, namely class X.E5 consisting of 35 students as the experimental class, and class X.E4 consisting of 40 students as the control class. The primary data in this study include the results of a questionnaire on the analysis of teaching material needs for chemistry subject teachers, the results of validation by material experts and media experts, the results of the effectiveness test of teaching materials in the form of cognitive test results on Stoichiometry material and environmental literacy of students, the results of user response assessments through reviews by chemistry teachers and the provision of student responses after using the teaching materials. Secondary data was obtained from lesson reports on the nearpod platform.

The data collection technique in this study was carried out using test and non-test methods. Initial research data was collected through a questionnaire using Google Forms for MA Chemistry teachers in Jepara Regency. Further data collection is carried out through validation of teaching materials by material experts and media experts, the results of which are used as data to determine the suitability of teaching materials based on the Aiken's V Index value (validity), Percentage of Agreement (reliability) and the percentage of suitability. The implementation test was conducted by utilizing the report feature on Nearpod. The implementation of teaching materials is reviewed from the perspective of student participation which is based on the percentage of students who answered questions correctly in the nearpod activity feature. If the results of the implementation of the teaching materials show "good" criteria, it can be concluded that the teaching materials can be implemented effectively in real learning situations. Further data collection was carried out by testing the effectiveness of teaching materials in improving learning outcomes and environmental literacy of students in the form of pretest-posttest. In addition, data collection was also carried out regarding user response assessments by filling out assessment sheets by reviewers, namely Chemistry teachers, and filling out student response questionnaires after using the teaching materials.

The instruments used in this study included cognitive tests on stoichiometry material, environmental literacy instruments, and user response questionnaires, namely students and chemistry teachers.

The data analysis process combines various methods to evaluate the feasibility and effectiveness of teaching materials. The validity test of teaching materials, the validity test of the content of cognitive test instruments and environmental literacy instruments was carried out by calculating the Aiken'sV index value.

The formula for calculating the Aiken's V index is as follows:

$$V = \frac{\Sigma s}{n(c-1)}$$

Where:

V = Validity index V or content validity value

S = r – Io

Io = lowest validity assessment score

C = highest validity assessment score

r = score given by an assessor

The validity criteria for calculating the Aiken's V index are presented in Table 1

Tabel 1. Validity Level

Value	Category
$V \leq 0{,}4$	Low
$0{,}4 < V < 0{,}8$	Medium
$V \geq 0{,}8$	High

Source : (Masithah et al., 2022)

Test the construct validity of the cognitive question instrument and environmental literacy instrument using the SPSS 23 program by conducting a correlation between each indicator score and the total score of the main variable. The product reliability test uses the Percentage of Agreement value, with the following formula:

$$\textit{Percentage of Agreement}\ (PA) = \left(1 - \frac{A-B}{A+B}\right) \times 100\%$$

Description:

PA: Instrument reliability (percentage of agreement)

A: Highest validator score for one variable

B: Lowest validator score for one variable

According to Borich (in (Arifuddin et al., 2022), if the percentage of agreement is greater than or equal to 75%, the instrument can be considered reliable. Reliability test for the cognitive test questions and environmental literacy instruments uses the SPSS 23 program by looking at the Cronbach Alpha value.

Hypothesis testing using independent sample t-test using the SPSS 23 program to determine the differences in learning outcomes and environmental literacy between the control class and the experimental class by first conducting a normality and homogeneity test of the data. If the normality and homogeneity of the data are not met, then another appropriate test is used. After it was discovered that there were differences in students' learning outcomes and environmental literacy, the N-gain test was continued. The increase that occurred before and after learning was calculated using the g factor (N-Gain) formula according to (Meltzer, 2002) as follows:

$$\langle g \rangle = \frac{Skor\ Postes - Skor\ Pretes}{Skor\ Maks - Skor\ Pretes}$$

Interpretation *N-Gain* according to (Hake, 1999) presented in Table 2

Table 2. Classification Interpretation <g>

<g>	**Interpretation**
$\langle g \rangle \geq 0.7$	Tall
$0.3 \leq \langle g \rangle \leq 0.7$	Currently
$\langle g \rangle < 0.3$	Low

The correlation between learning outcomes and students' environmental literacy was analyzed using a bivariate correlation test with the Pearson Product Moment correlation technique with the provision that the correlated variables are in the form of normally distributed data and the regression is linear. Pearson correlation analysis with the Correlate-Bivariate test was carried out using the SPSS 23 program. Determining the significance between variable X and variable Y is done using the testing criteria, namely: If the significance > 0.05 then Ho is accepted, if the significance < 0.05 then Ho is rejected. Then, to see the level of relationship between variable X and variable Y, the correlation coefficient interpretation table can be used:

Table 3. Interpretation of Correlation Coefficient

Coefficient Level	Relationship Level
0.00 - 0.199	Very Low
0.20 – 0.399	Low
0.40 – 0.599	Strong Enough
0.60 – 0.799	Strong
0.80 – 1.00	Very strong

Source: (Mayang Sari et al., 2023)

RESULTS AND DISCUSSION

Characteristics of Teaching Materials

The stoichiometry teaching materials developed have unique characteristics as a response to learning needs in senior high schools. Based on the results of observations and interviews, it was found that chemistry learning on the topic of stoichiometry often experiences obstacles due to its abstract nature, lack of context, and minimal student involvement in learning activities. Therefore, the development of this teaching material is aimed at answering these challenges through the integration of the Problem Based Learning (PBL) approach, the values of the Sustainable Development Goals (SDGs), and the use of digital technology in the form of the Nearpod platform.

Structurally, the teaching materials are developed in the form of interactive lessons that can be accessed via laptop or smartphone. Each topic in the teaching materials contains important components such as: cover, learning objectives, and introduction to the material. The main material covers five essential topics in stoichiometry: relative atomic mass and relative molecules, the concept of moles, empirical and molecular formulas and hydrate compounds, reaction stoichiometry and limiting reagents, as well as the percentage of elements in compounds, percent yield, and purity.

The PBL syntax used in teaching materials follows five main stages: 1). Orienting students to the problem, 2). Organizing students for learning, 3). Guiding individual and group investigations, 4). Developing and presenting discussion results, 5). Analyzing and evaluating the problem-solving process (Arends, 2012).

The initial phase begins with an explanation of global problems based on SDGs, such as the energy crisis, air pollution, plastic waste, and vehicle emissions. This approach has proven effective in improving students' problem-solving abilities because it links learning to the real world (Corres et al., 2020) and improve student motivation and learning outcomes (Arifiani et al., 2025). Thus, the PBL approach is an optimal method in learning chemistry on stoichiometry material which requires problem-solving skills (Fuzi & Yahaya, 2024) . PBL is also an optimal method for ESD (Tejedor et al., 2019). The integration of SDGs in chemistry learning is considered important because it encourages students not only to understand scientific concepts, but also to be able to apply them in the context of sustainable development. As stated by (Rieckmann & Gardiner, 2017), environmental and scientific literacy are important pillars in 21st century learning.

The Nearpod platform is used as an interactive learning media that supports the PBL process. Each lesson is equipped with features such as videos, open-ended questions, fill-in-the-blanks, and quizzes. The use of this technology can increase student engagement and learning outcomes, in line with the findings of who stated that the use of Nearpod increases students' active participation in learning activities on exothermic and endothermic reactions. Digital-based interactive platforms significantly not only complement conventional instruction but also empower students to explore, understand, and excel in the nuances of chemistry (Fuzi & Yahaya, 2024). In addition, teaching materials that integrate PBL with ESD also support the development of students' environmental literacy, as research by (Zulfah et al., 2024) shows.

The SDGs-integrated PBL-based stoichiometry teaching materials developed using Nearpod have the following characteristics: 1) Contextual and based on real-world problems, 2) Integrating sustainability values to support strengthening environmental literacy, 3) Utilizing digital technology to create interactive and flexible learning.

Eligibility of Teaching Materials

The suitability of teaching materials is a crucial aspect in research and development (R&D) to ensure that the products developed meet the quality standards of content, presentation, and implementation in real learning contexts. In this study, the feasibility testing process was carried out through three systematic stages, namely: define, design, and develop in accordance with the development model developed by (Thiagarajan, 1974) in the 4-D model (Four-D Model). Needs analysis conducted through observation and interviews shows that stoichiometry learning in schools uses conventional teaching materials which are limited in number, less contextual, and have not integrated sustainability values. This has an impact on low learning outcomes, as well as the need to increase students' environmental literacy. As a solution, teaching materials are designed by integrating the Problem Based Learning (PBL) model, SDGs values, and the use of digital technology through the Nearpod platform. Each stoichiometry topic is linked to a relevant environmental issue, such as alternative energy, plastic waste, and vehicle emissions. The product design follows PBL syntax and includes interactive features such as videos, open-ended questions, and multiple-choice quizzes.

Validation was carried out by two experts and one practitioner to assess the product in terms of material and media using indicator-based instruments. The validation results show that: the Aiken's V value of the material expert: 0.898 (high category), the reliability of the material expert (PA): 98.87% (reliable), and the percentage of the material expert's suitability: 92.36% (very suitable). Aiken's V value of media experts: 0.939 (high category), media expert reliability (PA): 97.6% (reliable), percentage of media expert suitability: 95.45% (very suitable). The results of this validation ensure the suitability of the content, readability, and interactivity of the teaching materials before they are implemented.

The validity and reliability of the cognitive and environmental literacy test instruments were also tested: validity of cognitive questions (Aiken's V): 0.961 (high category), reliability of cognitive questions (Cronbach's Alpha): 0.900 (reliable category), validity of environmental literacy instruments (Aiken's V): > 0.80 in all aspects, reliability of environmental literacy instruments: between 0.68 – 0.81 (reliable). The instrument was declared valid in terms of content and construct, in accordance with the validity criteria according to (Herispon et al., 2020).This ensures that the assessments used to evaluate the effectiveness of the teaching materials are accurate and reliable.

The implementation test was conducted on class XI students of MAN 1 Jepara by utilizing the report feature on Nearpod. The results of student participation in completing activities in the teaching materials showed an implementation rate of 79%, with a "good" category (Amaliah et al., 2016). This shows that the teaching materials can be implemented effectively in real learning situations. The suitability of the teaching materials is also strengthened by the results of student responses (implementation test): 72.86% (feasible/interesting category), the results of student responses (effectiveness test): 69% (feasible/interesting category), and the results of the chemistry teacher reviewer's assessment: 85% (very feasible category).

Teacher comments highlighted that the teaching materials were motivating for students, easy to understand, and engaging, but suggested increasing the number of case study questions and interactive features. This finding is in line with the view that student engagement and teacher acceptance are important indicators in measuring the acceptability of teaching materials in the field (Akker et al., 2013).

The SDGs-integrated PBL-based stoichiometry teaching materials assisted by Nearpod meet the criteria of "very appropriate" in terms of content, presentation, media, as well as implementation and user acceptance. The validation process and field testing show that this product is not only academically qualified, but can also be applied effectively in real classrooms. Therefore, this teaching material has the potential to be adopted as an innovation in chemistry learning that supports the achievement of essential competencies and increases environmental literacy.

Effectiveness of Teaching Materials

The effectiveness of a teaching material shows the extent to which the developed learning product is able to have a positive impact on the achievement of student competencies. In this context, the effectiveness was tested through a quasi-experimental pretest-posttest control group design that compared two groups: an experimental class that used innovative teaching materials, and a control class that used conventional teaching materials.

Improving Cognitive Learning Outcomes

Measurement of learning outcomes is carried out using multiple choice instruments equipped with descriptions/reasons for answers that have undergone validity and reliability tests. The 0–1–2 (polytomous) scoring system to capture students' thinking processes, following the recommendations of (Ramsay et al., 2025; Wallmark et al., 2024), that argument-based scoring is able to provide a more comprehensive picture of conceptual understanding. The pretest and posttest scores for the control class and the experimental class are presented in Figures 1 and 2 below.

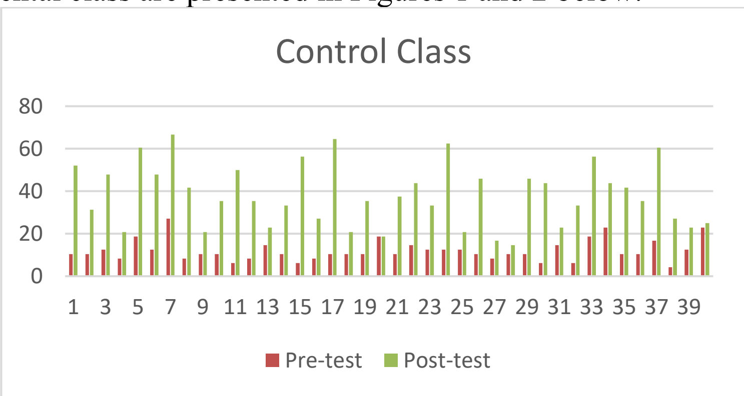

Figure 1. Pre-test and Post-test Scores of Learning Outcomes in the Control Class

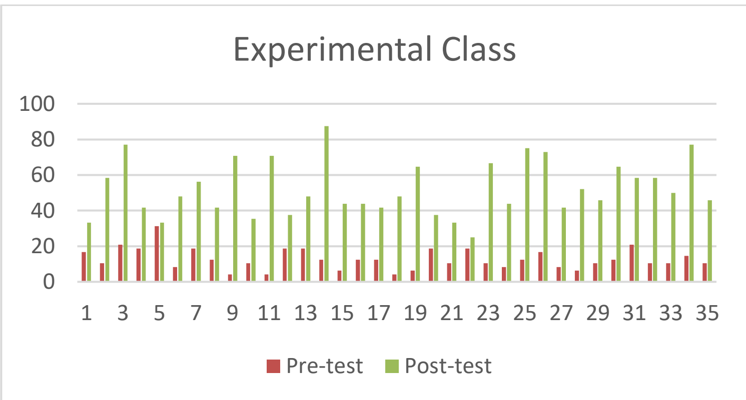

Figure 2. Pre-test and Post-test Scores of Experimental Class Learning Outcomes

Based on the normality test and data homogeneity test, the post-test data for the control class and the experimental class were normally distributed and came from homogeneous variance, so the hypothesis test was carried out using parametric statistics, namely the independent sample t-test. The results of the independent sample t-test showed that there was a significant difference between the post-test scores of the experimental class (mean = 52.34) and the control class (mean = 38.10), with a significance value of <0.05. This indicates that the use of PBL-based teaching materials integrated with SDGs assisted by Nearpod has a positive impact on student learning outcomes. The results of the independent sample t-test are presented in Table 4.

Table 4. Results of the Independent Sample T-test

Group Statistics

Class		N	Mean	Std. Deviation	Std. Error Mean
Cognitive Outcome Value	Posts control class	40	38.10	14,634	2,314
	Posts class experiment	35	52.34	15,463	2,614

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Nilai Hasil Kognitif	Equal variances assumed	0,096	0,757	-4,095	73	0,000	-14,243	3,478	-21,174	-7,312
	Equal variances not assumed			-4,080	70,450	0,000	-14,243	3,491	-21,204	-7,282

Furthermore, the N-Gain value for the experimental class was 0.45 (medium category), while the control class was only 0.29 (low-medium category). This difference indicates that the learning approach applied in the developed teaching materials is able to encourage increased understanding of stoichiometry concepts more effectively. PBL strategies enable learners to actively engage in contextual problem-solving processes, while SDG integration and the use of Nearpod help deliver relevant and interactive learning experiences. This finding strengthens the results of previous studies which stated that the PBL approach can improve students' understanding of chemical concepts and problem-solving abilities (Hmelo-Silver, 2004) ; (Corres et al., 2020) and increase student motivation and learning outcomes (Arifiani et al., 2025 ; Dhakiroh et al., 2024). Adoption of digital technologies such as Nearpod has also been shown to increase student interactivity and engagement in chemistry learning (Naumoska et al., 2022) ; (Fuzi & Yahaya, 2024).

Improving Environmental Literacy

Environmental literacy aspects are measured through four dimensions: environmental competence, environmental knowledge, attitudes towards the environment, and behavior towards the environment. The instruments used have been declared valid and reliable. The pretest and posttest scores for the control class and the experimental class are presented in Figures 3 and 4 below.

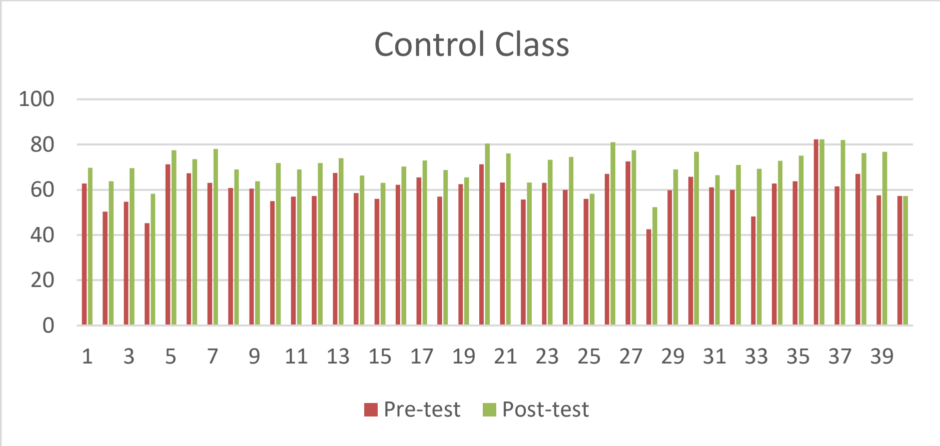

Figure 3. Pre-test and Post-test Scores of Environmental Literacy in the Control Class

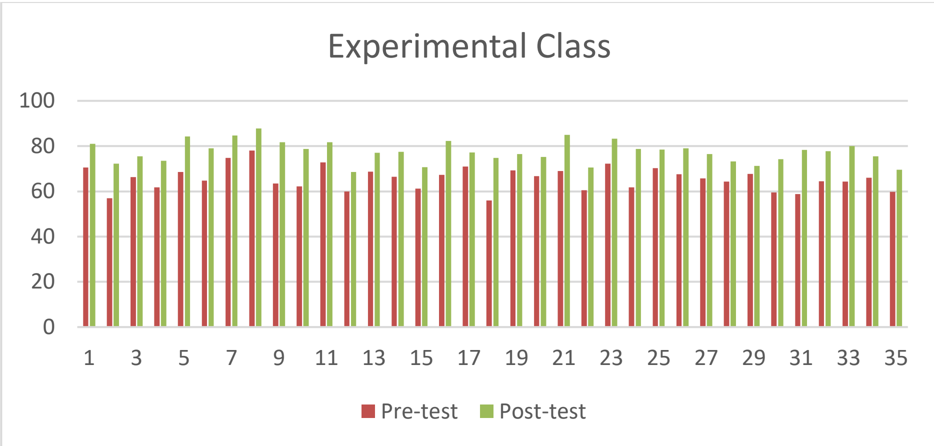

Figure 4. Pre-test and Post-test Scores of Environmental Literacy in the Experimental Class

The results of the Welch's t-Test showed that there was a significant difference between the environmental literacy scores of the experimental class and the control class ($F = 24.668$, $p < 0.001$), with a non-homogeneous variance but normal distribution. The results of the Welch's t-Test are presented in Table 5.

Table 5. Results of Welch's t-Test

Robust Tests of Equality of Means

post test literasi

	Statistic[a]	df1	df2	Sig.
Welch	24,668	1	67,745	0,000
Brown-Forsythe	24,668	1	67,745	0,000

a. Asymptotically F distributed.

The N-Gain analysis shows that the experimental class had an improvement score of 0.34 (medium category), while the control class only had 0.25 (low category). These findings indicate that the integration of global sustainability issues into stoichiometry material through the PBL approach not only improves students' conceptual understanding, but also builds their awareness and concern for environmental issues. These results support (Rieckmann & Gardiner, 2017) opinion that contextual learning that integrates sustainability issues can significantly improve students' environmental literacy.

According to Mitarlis et al. (2017), environmental literacy is very important for 21st century students to develop responsible behavior towards the environment (Ariyatun et al., 2024). The use of a PBL approach based on real environmental problems (renewable alternative energy, vehicle emissions, plastic waste, used cooking oil) integrated into teaching materials has proven effective in achieving these objectives.

The results of the study show that the SDGs-integrated PBL-based stoichiometry teaching materials assisted by Nearpod: 1). Effectively improve students' cognitive learning outcomes significantly compared to conventional teaching materials 2). Effectively improve environmental literacy, both in terms of competency, knowledge, attitude, and behavior 3). Meet the criteria as an innovative 21st-century learning media that combines modern pedagogy, sustainability values, and interactive digital technology.

Therefore, this teaching material is highly recommended to be implemented in chemistry learning in schools as an effort to improve the quality of science education that is contextual, relevant, and environmentally aware.

Correlation Between Learning Outcomes and Environmental Literacy

This study found that there is a positive and significant relationship between students' cognitive learning outcomes and environmental literacy, which was analyzed using the Pearson Product Moment correlation test. Before conducting the correlation test, a prerequisite test was carried out in the form of a normality and linearity test which showed that the two variables (learning outcomes and environmental literacy) were normally distributed and had a linear relationship.

The linearity test shows that the significance value of deviation from linearity is 0.152 (> 0.05), so it can be concluded that the relationship between learning outcomes and environmental literacy is linear. Linearity of the relationship is an important requirement in Pearson correlation analysis (Tampubolon & Sianturi, 2020). Pearson correlation analysis shows a correlation coefficient value of $r = 0.405$ with a significance of $p = 0.000$. Because $p < 0.01$, this relationship is significant at the 1% level. This means that there is a significant positive relationship between learning outcomes and environmental literacy in the fairly strong correlation category (r between 0.40–0.59) according to the interpretation put forward by (Mayang Sari et al., 2023). This finding indicates that the higher the students' learning outcomes in chemistry learning, the higher their level of environmental literacy. On the other hand, low mastery of chemical concepts can have an impact on low awareness and ability of students in understanding science-based environmental issues. These results are in line with the view that a good understanding of chemical concepts can help students assess and analyze environmental problems scientifically, especially when these concepts are integrated in a global context such as the SDGs.

This positive correlation shows that understanding chemical concepts, especially stoichiometry, integrated with sustainability issues can strengthen students' environmental literacy competencies. This is in line with the findings of the (OECD, 2019) in the PISA Framework, which emphasizes the importance of integrating scientific literacy and global issues in learning to form citizens who think critically and care about the environment. In addition, the Problem Based Learning (PBL) approach has been proven to not only improve cognitive mastery, but also facilitate the development of ecological values through solving real problems (Hmelo-Silver, 2004 ; Corres et al., 2020).

Based on Pearson correlation analysis, this study proves that: 1) There is a significant positive relationship between learning outcomes and students' environmental literacy ($r = 0.405$; $p < 0.01$) 2). The relationship is quite strong and linear 3). Improving learning outcomes in contextual learning based on PBL and SDGs has the potential to directly encourage increased environmental literacy.

These findings emphasize the importance of integrating chemistry content with environmental issues and the application of modern pedagogy to achieve meaningful 21st-century learning.

CONCLUSION

The SDGs-integrated PBL-based stoichiometry teaching materials assisted by Nearpod have innovative characteristics, are feasible to use, are effective in improving learning outcomes and environmental literacy, and show a positive relationship between the two. It is recommended for teachers to implement this teaching material as an alternative learning media, and for further researchers to expand its development to other materials and other 21st century skills variables.

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