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Development of Project-Based Learning Student Activity Sheets to Improve Scientific Literacy Skills on Green Chemistry Materials

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Abstract: The demands of 21st-century science education emphasize the development of scientific literacy and sustainability awareness, necessitating the integration of Project-Based Learning and green chemistry–oriented learning materials. This research aims to develop Student Activity Sheets (SAS) based on Project-Based Learning (PBL) to enhance students' scientific literacy skills related to green chemistry materials. The research method used is Research and Development (R&D) with the 4D model (Define, Design, Develop, Disseminate) limited to the develop stage. The research subjects were 32 grade XI students at MA Unggul Sabira-IIBS Mojokerto. The validity of SAS was assessed by two chemistry lecturers and one chemistry teacher, yielding a validity mode score of 5, indicating very valid criteria. The practicality of SAS was measured through student response questionnaires, obtaining 96.52% (very practical), learning implementation observation with mode 5 (very good), and student activity observation with mode 5 (very good). The effectiveness of SAS was measured through a pretest-posttest of scientific literacy skills with an average N-gain of 0.83 (high category). The results showed that 90% of students experienced significant improvement, with an N-gain of 0.7 or greater. The SAS developed contains three projects: eco-enzyme as organic fertilizer, cloth pads, and natural room fresheners from lime and coffee, all integrated with green chemistry principles and scientific literacy domains. Thus, the SAS based on PjBL is feasible (valid, practical, and effective) for improving students' scientific literacy skills in green chemistry materials.

Keywords: Green Chemistry; Project-Based Learning; Scientific Literacy; Student Activity Sheets.

Introduction

Education is a crucial process for developing human potential and must evolve in response to the advancements in science and technology in the 21st century. Scientific literacy is a key skill in science education, but the 2023 PISA results indicate that Indonesian students' scientific literacy remains low [1]. Green chemistry has emerged as an important approach to developing environmentally friendly chemical processes.

Green chemistry learning greatly helps students understand chemical concepts in a relevant way while instilling awareness of sustainable development. Green chemistry aims to minimize the use of hazardous materials to overcome environmental pollution. The integration of green chemistry in education enhances learning quality and equips students with the skills to address future environmental challenges [2]. The success of this learning depends on the teacher's ability to create an effective learning environment. In addition to the PjBL approach, improving scientific literacy through project and technology-based learning is also an important aspect of modern education systems.

The use of Student Activity Sheets (SAS) based on scientific literacy and Green Chemistry has proven effective in improving concept understanding and environmental awareness [3]. Project-based learning with Green Chemistry SAS media enables students to conduct projects directly, process data, and draw conclusions independently, thereby developing critical and analytical thinking skills more effectively [4]. The latest scientific literacy report, particularly relevant to research in Indonesia, indicates that the scientific literacy abilities of junior high school students remain relatively low. One of them, a study at SMP Negeri 54 Surabaya, found the success percentage of students in three main PISA scientific literacy indicators, namely explaining scientific phenomena (34.4%), evaluating and designing scientific investigations (36.6%), and interpreting data and scientific evidence (33.3%), all in the low category [5]. Pre-research data results conducted at the MA Unggul Sabira class XI female showed that students' scientific literacy abilities on three scientific literacy competencies obtained percentages of 7.16%, 4.66%, and 8.04%.

These low percentage results show students still have limited abilities in applying the three scientific literacy competencies. Thus, students' scientific literacy abilities can be categorized as still low, where only a small portion of students are able to use their content knowledge, procedural knowledge, or epistemic knowledge to provide explanations, evaluate and design scientific questions, and interpret data from various phenomena in daily life that require low cognitive levels. The pre-research questionnaire results showed that 68.76% of students were not interested in green chemistry materials because they were often delivered through lecture methods. This indicates that the chemistry learning process has not led to scientific literacy-based learning, as students have not been given sufficient space to develop their attitudes, knowledge, and skills. As many as

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96.88% of students expect to learn using a practicum on green chemistry materials, hoping the learning process will be more meaningful, according to their wishes.

Based on the description above, this research aims to explore further how the application of PjBL, scientific literacy, and Green Chemistry in chemistry learning can improve students' conceptual understanding, critical thinking skills, and environmental awareness. Therefore, researchers developed SAS based on Project Based Learning on green chemistry material which is expected to improve students' scientific literacy abilities.

Research Methods

This research employs the Research and Development (R&D) method, as designed by Thiagarajan and Semmel (1974), utilising the 4D (Define, Design, Develop, Disseminate) model [6]. However, this research is limited to the develop stage due to time, energy, and cost constraints. The research was conducted at MA Unggul Sabira-IIBS Mojokerto with 32 grade XI students as research subjects.

Data collection was conducted through several instruments, including validation sheets to assess SAS validity, observation sheets on learning implementation to evaluate the practicality of the learning process, observation sheets on student activities to assess student involvement, student response questionnaires to evaluate SAS user-friendliness, and pretest-posttest tests of scientific literacy abilities to measure the effectiveness of SAS.

Table 1. Likert Scale

Criteria	Scale Value
Very inappropriate	1
Not enough	2
Enough	3
Good	4
Very good	5

Validation data were analyzed using mode because the data are ordinal and cannot be processed mathematically. SAS is declared valid if it obtains a mode score ≥ 4 with good to very good criteria [8]. For practicality assessment, observation data of learning implementation and student activities were analyzed using a Likert scale with criteria.

Table 2. Likert Scale

Criteria	Scale Value
Very inappropriate	1
Not enough	2
Enough	3
Good	4
Very good	5

Data were analyzed using the mode with the criterion of practicality if the mode score ≥ 4. Student response data were collected using Guttman scale with scoring: answer "Yes" = 1 and "No" = 0 for positive statements while answer "No" = 1 and "Yes" = 0 for negative statements [12].

Table 3. Guttman Scale

Question	Answer	Score
Positive	Yes	1
	No	0
Negative	Yes	1
	No	0

Response data were analyzed using percentages with the formula:

$$(\%)\text{Response Percentage} = \frac{\text{Total score obtained}}{\text{Number of respondents}} \text{ X } 100\%$$

SAS is considered practical if it achieves a student response percentage of≥ 61% with good to very good criteria [8]. For effectiveness assessment, pretest-posttest data of scientific literacy abilities were analyzed using the N-gain formula:

$$< g >= \frac{\text{Sposttest} - \text{Spretest}}{\text{Smaks} - \text{Spre}}$$

where <g> is the normalized gain, Spost is the posttest score, Spre is the pretest score, and Smaks is the maximum score [7]. N-gain interpretation criteria are:

Table 4. N-Gain Value Index

N-gain	Criteria
g> 0,7	High
0,3 ≤ g ≥ 0,7	Medium
g < 0,3	Low

SAS is declared effective if it obtains N-gain ≥ 0.3 with medium to high criteria. In addition, a normality test using the Shapiro-Wilk method and a paired sample t-test were conducted to determine significant differences between pretest and posttest scores, with a significance level of α = 0.05.

Results and Discussion

The first stage is the define stage, which includes five main steps: front-end analysis, learner analysis, concept analysis, task analysis, and formulation of learning objectives. Front-end analysis was conducted through interviews with chemistry teachers and the distribution of pre-research questionnaires to grade XI students to identify problems in chemistry learning. Learner analysis was conducted to map student characteristics, including age, cognitive development, and academic abilities. Concept analysis was conducted by identifying the key concepts in green chemistry materials that need to be taught effectively. Task analysis aims to identify competencies that must be mastered according to the Independent Curriculum and Chemistry Learning Achievements. The formulation of learning objectives was carried out by referring to the Learning Achievement Flow that has been established in the chemistry learning achievement.

The second stage is the design stage, which includes test preparation, selection of teaching materials, selection of presentation format, and initial design. Tests developed include a pretest-posttest for scientific literacy abilities in essay form, designed according to PISA characteristics, covering context, knowledge, competency, and attitude domains. The SAS consists of three parts: SAS 1 about making organic fertilizer from eco-enzyme, SAS 2 about making cloth pads, and SAS 3 about making natural room fresheners from lime and coffee. Each SAS is designed by integrating the six phases of Project-Based Learning with green chemistry principles and scientific literacy domains.

The third stage is the develop stage, which includes expert assessment through review and validation, SAS revision, and a limited trial. A review was conducted by a supervising lecturer to gather input and suggestions for improvement prior to the validation process. Validation was conducted by two chemistry lecturers from Universitas Negeri Surabaya and one chemistry teacher from MA Unggul Sabira-IIBS to assess the feasibility of SAS from content validity and construct validity aspects. After being declared valid, SAS was revised according to the validator's suggestions and then tested in a limited trial with 32 grade XI students at MA Unggul Sabira-IIBS Mojokerto.

The first domain is the context of science literacy, where the context in science literacy is realized through the delivery of relevant and current issues in each SAS. The context presented encompasses personal aspects, including individual life, local aspects, such as the community, and global aspects, including the environment. The second domain is science literacy knowledge, which encompasses three types of knowledge: content knowledge, procedural knowledge, and epistemic knowledge. The content knowledge in this SAS is green chemistry material, which covers 12 principles of green chemistry and their applications in everyday life. Students learn principles such as waste prevention, atom economy, safe synthesis, use of renewable raw materials, use of catalysts, energy efficiency, safe solvents and reaction conditions, biodegradable products, direct analysis, minimizing the potential for accidents, and effective and minimally toxic product design. The third domain is science literacy competency, which in this SAS encompasses three main aspects in accordance with the PISA framework. In addition to these three main domains, this SAS also fosters scientific identity, particularly by cultivating an interest in science. This can be seen from the reflections on feelings after completing the project, the enjoyable learning experience through hands-on project activities, and the relevance of the material to real life, which increases interest in learning.

The science literacy component on each page of the SAS is marked with a box or highlight that explains which science literacy domain is being developed, making it easier for teachers and students to identify the aspects of science literacy being studied and making the learning process more focused and meaningful.

The developed SAS consists of three main projects that systematically integrate green chemistry principles with science literacy domains to enhance students' understanding of sustainable chemistry practices. The following examples illustrate the implementation of science literacy domains in SAS, demonstrating how theoretical concepts are applied in practical settings. In SAS 1 (Eco-enzyme), multiple green chemistry principles are strategically incorporated, including principle 1 (waste prevention), which emphasizes reducing waste generation at the source; principle 2 (atomic economy), which focuses on maximizing the incorporation of all materials used in the process into the final product; principle 4 (renewable raw materials), which promotes the use of sustainable and biodegradable resources; principle 6 (energy efficiency), which encourages processes that require minimal energy input; and principle 7 (reduction of derivatization), which minimizes unnecessary chemical modifications. This comprehensive integration helps students understand not only the theoretical framework of green chemistry but also its concrete application in addressing pressing environmental issues such as organic waste management and sustainable resource utilization.

SAS effectively presents science concepts across three interconnected contexts: personal, local/national, and global perspectives. In SAS 1 (Eco-enzyme), the phenomenon of fruit waste accumulation at Kota Baru Central Market is strategically presented as a local/national context that is directly relevant to students' daily lives and community experiences. This contextualization allows students to recognize the immediate impact of waste management challenges in their own environment, fostering a sense of personal responsibility and connection to broader sustainability efforts. By anchoring abstract green chemistry principles in familiar, observable situations, students can more effectively bridge the gap between classroom learning and real-world problem-solving, ultimately developing critical scientific literacy skills that extend beyond theoretical knowledge to practical environmental stewardship. As can be seen in the following figure.

Figure 1. Phase 1 PjBL with science literacy domain

This context domain trains students to identify environmental problems in their surroundings and relate them to concepts of green chemistry. Students are asked to formulate a problem statement: How does the accumulation of household waste in the new city's central market affect the environment and public health, and what innovations can be developed to manage this waste sustainably? Next, procedural knowledge is developed through the project design phase, where students design procedures for making eco-enzymes by determining the tools, materials, and systematic work steps. environmental problems around them and relate them to green chemistry concepts. Students are asked to formulate a problem statement: how does the accumulation of household waste in the new city's central market affect the environment and public health, and what innovations can be developed to manage this waste sustainably? Next, procedural knowledge is developed through the project design phase, where students design procedures for making eco-enzymes by determining the tools, materials, and systematic work steps. As can be seen in the following figure.

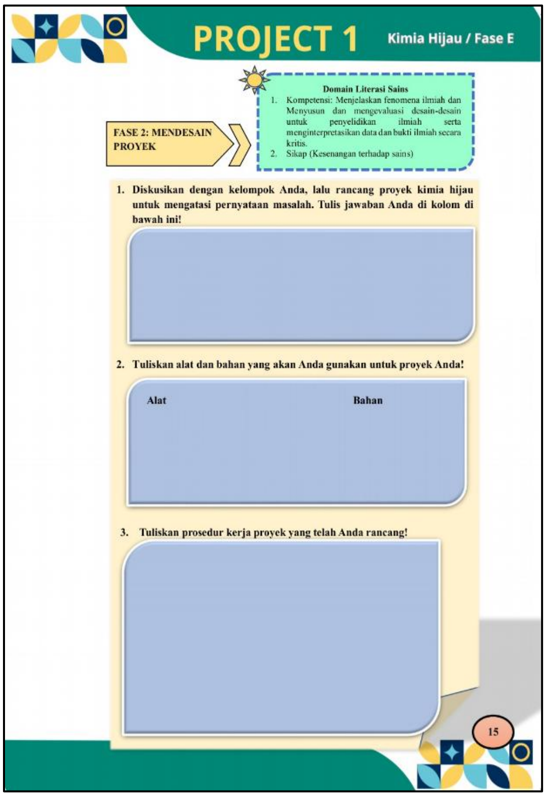

Figure 2. Phase 2 PjBL with science literacy domain

The science literacy competency domain is trained throughout all phases of PjBL. In the monitoring phase (Phase 4), students interpret the observation data. Students systematically record changes in color, pH, odor, temperature, and volume, then analyze the data to answer questions such as, What do the changes in the color of the solution from clear yellow to dark brown during fermentation indicate. This trains students in the competency of critically interpreting data and scientific evidence, which is one of the three main science literacy competencies according to PISA. The last one is the Attitude domain, which is developed through reflection at the end of each project. Students are asked to reflect on their feelings and the environmental awareness that has been formed. As can be seen in the Figure 4.

In this final phase, students are asked to draw conclusions about the results of the project they have carried out. Students write conclusions linking the product they have made with the principles of green chemistry and its impact on the environment. In addition, students are also asked to reflect on their feelings after completing the project by checking the appropriate emoji (very happy, happy, neutral, sad, or very sad). This phase develops a scientific identity characterized by an enjoyment of science and an awareness of meaningful learning.

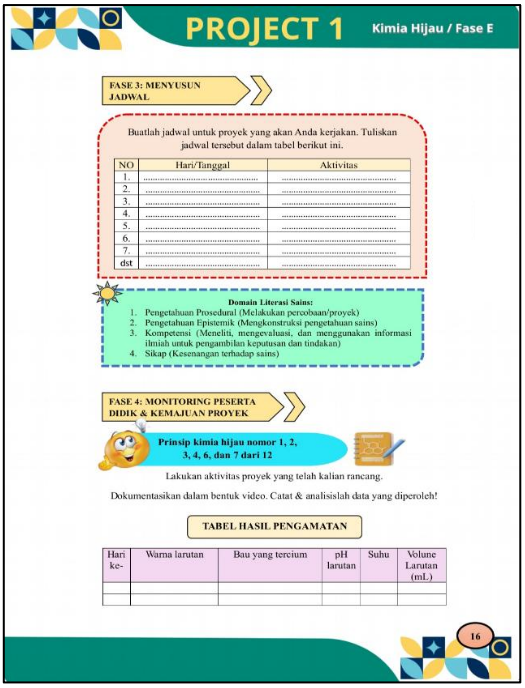

Figure 3. Phase 4 PjBL with science literacy domain

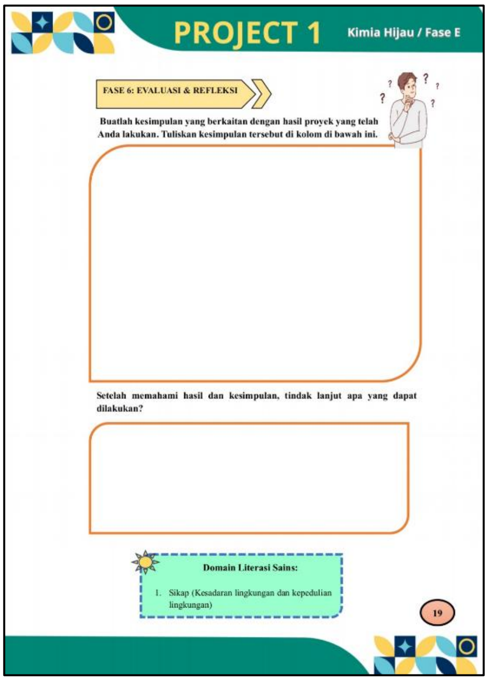

Figure 4. Phase 6 PjBL with science literacy domain

Validity

The validity assessment of SAS was conducted by three validators, consisting of two chemistry lecturers and one chemistry teacher. The validation results indicate that SAS achieved a mode score of 5, meeting very stringent criteria for both content validity and construct validity aspects.

Content validity encompasses the suitability of SAS in relation to learning achievements and objectives, its alignment with the Project-Based Learning model, its suitability in relation to scientific literacy domains, the accuracy of images/illustrations, and the accuracy of the bibliography. All components obtained mode scores between 4 and 5, meeting valid to very valid criteria.

Table 5. Content Validity Result of SAS

Assessed Aspect	V1	V2	V3	Mode	Criteria
Suitabily with learning achivements	4	4	5	4	Valid
Suitabily with learning objectives	4	4	5	4	Valid
Suitabily with PjBL model	5	5	5	5	Very Valid
Suitabily with scientific literacy domains	4	4	5	4	Valid
Accuracy of images/illustrastions	4	5	5	5	Very Valid
Accuracy of bibliography	5	5	5	5	Very Valid
Content Validity Mode				5	Very Valid

Table 6. Construct Validity Results of SAS

Persentase (%)	Mode	Criteria
Language Aspect	4	Valid
Persentation Aspect	5	Very Valid
Graphic Aspect	5	Very Valid

Based on Tables 5 and 6, the SAS obtained a mode score of 5 for both content validity and construct validity, indicating very valid criteria. Content validity encompasses suitability with learning achievements and objectives (mode 4), alignment with the PjBL model (mode 5), alignment with scientific literacy domains (mode 4), accuracy of images (mode 5), and accuracy of bibliography (mode 5). Construct validity includes language aspect (mode 4), presentation aspect (mode 5), and graphics aspect (mode 5). Thus, the SAS developed meets validity criteria and is suitable for use as a learning medium.

Practically

The practicality of SAS was assessed through student response questionnaires, observations of learning implementation, and observations of student activities. The practicality of SAS was assessed through student response questionnaires, observations of learning implementation, and observations of student activities. The results are presented in Table 7, Figure 5, and Table 8.

The observation of learning implementation and student activities aims to assess the practicality of using green chemistry-based SAS as a learning medium. The observation was conducted by five observers using the Project-Based Learning model, where observers filled out observation sheets by giving scores between 1 and 5 according to the categories of learning implementation that took place. The scores given were then analyzed using the mode method. The following are the results of observations on the implementation of learning activities using SAS.

Table 7. Student Response Questionnaire Results

Aspect	Percentage (%)	Criteria
Response to SAS	96.52%	Very Practical
Response to PjBL Learning	96.52%	Very Practical
Response to scientific literacy domains	96.52%	Very Practical
Average	96.52%	Very Practical

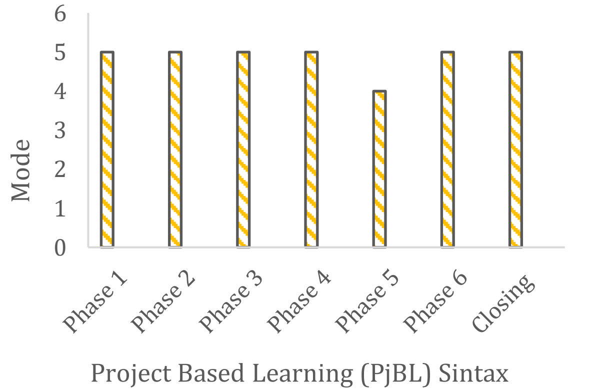

Figure 5. Learning Implementation Observation Results

Table 8. Student Activity Observation Results

Meeting	Mode Score	Criteria
Meeting 1	5	Very Good
Meeting 2	5	Very Good
Meeting 3	5	Very Good
Average Mode	5	Very Good

Based on Table 7, the student response questionnaire results show an average percentage of 96.52%, indicating very practical criteria. Figure 1 shows that the learning implementation observation results yielded a mode score of 5, meeting very good criteria for all three meetings. Table 8 shows that the student activity observation results obtained a mode score of 5, meeting very good criteria for all three meetings. Based on the three indicators, it can be concluded that the SAS developed is very practical to use. This aligns with Lutfi's opinion (2021), which states that SAS is considered practical if it achieves a percentage of student responses of$\geq$ 61% and a mode score for learning implementation and student activities of$\geq$ 4 [8].

In terms of student response to SAS, the average percentage shows very high results in the very practical category. Students responded positively to learning motivation, with 100% of students stating that SAS motivated them to learn. A total of 93.75% of students stated that SAS aroused their curiosity, and 93.75% reported that SAS was presented systematically in accordance with learning objectives, making it easy to understand. A total of 100% of students stated that the material in SAS was presented clearly and logically, which helped them work on questions related to green chemistry. Regarding the knowledge domain, 90.62% of students stated that the use of SAS helped them improve their understanding and increase their knowledge of green chemistry material. Regarding the context domain, 87.5% of students stated that the use of SAS helped them understand issues, phenomena, and problems in everyday life.

In the competency domain, 100% of students stated that the use of SAS helped them in designing and carrying out projects to solve problems. A total of 100% of students stated that SAS helped them in making essential questions relevant to green chemistry phenomena, 96.87% stated that SAS helped them in making conclusions based on scientific data and evidence, and 90.62% stated that SAS helped them in evaluating the results of scientific investigations or projects [13].

In the attitude domain, 93.75% of students stated that the use of SAS made them more likely to engage in science literacy in chemistry learning, and 96.87% stated that the use of SAS enabled them to be responsible and develop environmental awareness. In terms of design and presentation, 100% of students stated that the SAS cover design was presented with attractive colors and images, and 100% stated that the scientific language and terms used in the SAS were easy to understand and clear. A total of 90.62% of students stated that the SAS was presented with easy-to-understand instructions for use, 96.87% stated that the SAS contained questions that were easy to understand, 100% stated that the font size and type were easy to understand, and 100% stated that the use of tables, layout, and illustrations was appropriate [14].

Effectiveness

The effectiveness of SAS was measured through a pretest-posttest of students' scientific literacy abilities. The results are presented in Tables 9, 10, and 11.

Table 9. N-Gain Results of Scientific Literacy Abilities

Description	Value
Average Pretest Score	32.47
Average Posttest Score	88.91
Average N-gain	0.83
Criteria	High

Table 10. N-Gain Results of Scientific Literacy Abilities

Category	N-Gain Range	Number of Students	Percentage (%)
High	$g > 0.7$	27	84.37
Medium	$0.3 \leq g \leq 0.7$	5	15.63
Low	$g < 0.3$	0	0.00
Total			High

Table 11. N-Gain per Scientific Literacy Domains

Domain	Aspect	Pre-test	Post-test	N-gain	Criteria
Context	Global	15.62	90.62	0.93	High
	Local	28.12	93.75	0.91	High
	Personal	34.37	96.87	0.95	High
Knowledge	Content	37.50	96.87	0.95	High
	Procedural	18.75	90.62	0.88	High
	Epistemic	31.25	87.50	0.82	High
Competency	Explaining Phenomena	18.75	93.75	0.92	High
	Evaluating designs	9.37	87.50	0.86	High
	Interpreting data	3.12	90.62	0.90	High
Attitude	Self-effiacy	34.37	90.62	0.85	High
	Enjoyment	43.75	96.87	0.94	High
	Instrumental motivation	31.25	87.50	0.81	High

Based on Table 6, the average N-gain in students' scientific literacy abilities is 0.83, categorised as high. Table 7 shows that 27 students (84.37%) showed improvement in the high category and 5 students (15.63%) in the medium category. Table 8 shows that all scientific literacy domains experienced significant improvement with N-gain ranging from 0.81 to 0.95 in the high category. The highest N-gain was achieved in the context domain (personal aspect), with an N-gain of 0.95, while the lowest was in the attitude domain (instrumental motivation aspect), with an N-gain of 0.81, still in the high category. The paired sample t-test results show a significance value of $0.000 < 0.05$, indicating a statistically significant difference between the pretest and posttest scores. Thus, the SAS developed is effective in improving students' scientific literacy skills related to green chemistry materials [15].

The SAS developed integrates the six phases of Project-Based Learning with green chemistry principles and scientific literacy domains. Each phase is designed to train specific scientific literacy competencies. Phase 1 (Essential Question) trains competence in explaining scientific phenomena by presenting real phenomena related to environmental problems. Phase 2 (Project Design) trains students in designing scientific investigations by asking them to develop green chemistry projects. Phase 3 (Setting Up A Schedule) trains planning and time management skills. Phase 4 (Monitoring Students & Progress) trains competence in interpreting data and scientific evidence through systematic observation and data recording. Phase 5 (Preparing Reports & Presenting Products) trains scientific communication skills. Phase 6 (Evaluating & Reflecting Product) trains competence in evaluating and making decisions based on scientific evidence [16].

The three projects developed (eco-enzyme, cloth pads, and natural room fresheners) apply green chemistry principles, including the use of renewable raw materials, waste prevention, safe process utilisation, and the design of biodegradable products [17]. This aligns with the opinion of Mitarlis et al. (2017), who state that integrating green chemistry values into learning can enhance students' environmental awareness [9].

The observation of learning implementation and student activities aimed to assess the practicality of using green chemistry-based SAS as a learning medium. The observation was conducted by five observers using the Project-Based Learning model, where observers filled out observation sheets, assigning scores between 1 and 5 according to the categories of learning implementation that took place. The scores given were then analyzed using the mode method. The results of the observation of learning implementation in the three meetings showed that the learning took place very well and was in accordance with the Project-Based Learning syntax, with a mean score of 5 for all meetings [18].

The results of the analysis of student activity observations yielded a percentage in the range of 80% to 100%, indicating that the students followed all stages of Project-Based Learning, which included aspects of science literacy. In the first phase, which focused on essential questions, students examined the teacher's perception and motivation, reviewed prerequisite material, and worked on questions related to the basic knowledge of green chemistry outlined in the SAS. The science literacy aspect in this activity was content knowledge [19].

In the second phase, which involves designing the project, students identify problems arising from the presented phenomena, taking into account the aspect of science literacy, specifically contextual knowledge. Students also determine the experimental variables and formulate problems based on the phenomena before conducting the experiment.

In the third phase, which is scheduling, students write down hypotheses in accordance with the problem statements they made in the previous phase. Students also develop experimental procedures using the provided tools and materials. The scientific literacy aspects in this activity are procedural knowledge and experimental design skills. In the fourth phase, monitoring students and project progress, students conduct experiments on factors that affect the reaction rate, then analyze the experimental data and write it down in an observation table. The aspect of science literacy in this activity is the ability to interpret data and scientific evidence. Students record observation data systematically and conduct in-depth analysis of the experimental results.

In the fifth phase, which is testing the results, students connect the experimental data obtained with the problem formulation and then draw conclusions from the hypotheses that have been made. In the sixth phase, which is evaluation and reflection, students relate phenomena in everyday life, experimental activities, and conclusions from the experiments conducted. The science literacy aspect of this activity involves explaining scientific phenomena. Students also conduct evaluations after completing a series of lessons. The science literacy aspect of this activity is the skill of evaluating and making decisions based on scientific evidence. The results of the learning implementation observation indicate that learning took place in the three meetings, with a mode score of 5, indicating that all aspects of Project-Based Learning syntax were implemented effectively. The majority of aspects in each phase received a score of 5, with only a few aspects receiving a score of 4 (in the good category) in Meetings 2 and 3. The mode score of 5 in all three meetings shows consistency and high quality of learning. This aligns with Lutfi's (2021) opinion, which states that SAS is considered practical if it achieves a minimum mode score of 4, categorised as good to very good [20].

Learning using PjBL-based SAS has been proven effective in improving students' scientific literacy abilities. This finding is consistent with previous research, which has shown that PjBL can effectively train critical thinking skills, problem-solving abilities, and creativity in students, particularly when integrated with Green Chemistry concepts [10]. Additionally, PjBL enables students to connect theory with practice, making them more engaged in exploring scientific concepts [11].

The significant increase in students' scientific literacy abilities is also supported by the use of SAS, which comprehensively integrates the various domains of scientific literacy. This is consistent with PISA 2025, which emphasises that scientific literacy includes not only knowledge, but also competencies, contexts, and scientific attitudes [1]. Through direct experience in conducting projects, students can develop a holistic understanding of scientific literacy [21].

Conclusion

Based on research results and data analysis, it can be concluded that the Student Activity Sheets (SAS) based on Project-Based Learning are feasible for improving scientific literacy abilities related to green chemistry materials. This feasibility is indicated by: (1) SAS validity obtained mode score 5 with very valid criteria for both content validity and construct validity aspects; (2) SAS practicality obtained student response percentage 96.52% (very practical), learning implementation observation mode 5 (very good), and student activity observation mode 5 (very good); (3) SAS effectiveness obtained average N-gain 0.83 (high category) with 90% of students showing significant improvement (N-gain $\geq$ 0.7). Thus, the SAS developed can be used as an alternative learning medium to enhance students' scientific literacy skills in green chemistry materials.

Author's Contribution

R. Maimun: research design, instrument development, data collection, data analysis, and manuscript writing. Mitarlis: research supervision, manuscript review, and validation.

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