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Development of Learning Program Based on Multiple Representations Integrated with PjBL George Lucas and STEM to Foster Students' Sustainability Literacy

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Abstract

This study aims to describe the steps for developing a renewable energy learning program based on multiple representation integrated PjBL George Lucas and STEM to foster student sustainability literacy. This study uses mixed methods with R&D model ADDIE. Development of learning program based on multiple representations integrated PjBL STEM, namely lesson plans with syntax PJBL George Lucas and STEM, e-handout multiple representations with IF SO framework, LKPD PjBL STEM, comic renewable energy in everyday language and posters. Before being used the learning program was first validated by 3 experts, based on the assessment of experts who fulfill the very valid category with an average construct validation score of 4 and an average content validation value of 3.92. Learning programs that have been validated are then tested on SMA N 2 Kotabumi students are class XI MIPA 3 (experimental class) and class XI MIPA 2 (control class). The results of the research show that the learning program developed is effective in increasing sustainability literacy seen from the increase in N gains sustainability literacy in dimensions of knowledge (0.489), attitudes (0.529), skills (0.681) and behavior (0.839) in the experimental class which were higher than the control class, namely N literacy gains in the dimensions of knowledge (0.180), attitudes (0.341), skills (0.193) and behavior (0.419).It appears that the learning program developed is high at cultivating sustainability literacy on behavioral dimension, medium at training sustainability literacy on skills dimension, attitude and knowledge.
Keywords: Learning program; Multiple Representations; PjBL STEM; Sustainability Literacy; Renewable Energy;

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Introduction

Currently the world is faced with a condition of diminishing fossil-fuel energy, so new innovations are needed in the provision of renewable energy (Barry et al., 2017; Eshiemogie et al., 2022; Lund, 2007). In several developed countries, the issue of renewable energy has begun to be included and taught in the school curriculum to instill the importance of awareness of renewable energy (Barry et al., 2017; Eshiemogie et al., 2022; Ocetkiewicz et al., 2017). Therefore, the young generation

in Indonesia must get proper knowledge as citizens of the world in overcoming these problems and being part of the solution to global challenges and fostering students' sustainability literacy (Cebrián et al., 2020; Lopez-Medina et al., 2019; Lund, 2007; Probst et al., 2019; Russel et al., 2021). Sustainability literacy, in this case, is knowledge, attitude, and sustainable behavior related to energy efficiency and the production of renewable energy (Davis et al., 2009). This literacy can be fostered through the STEM approach (Barry et al., 2017). The STEM approach was developed by associating the concepts taught with real-world problems related to the environment (Pratiwi et al., 2021). STEM itself can be enhanced by multiple representations (Rau, 2017). The use of multiple representations in learning activities is urgently needed, especially for learning quite abstract concepts, such as in various count-based subjects such as Mathematics and Physics (Rau, 2017; Syahmel & Jumadi, 2020).

The problem is that learning Physics, especially the topic of renewable energy in Indonesia, does not involve local wisdom which facilitates various student learning needs (multiple representations) and does not foster students' sustainability literacy (Pratiwi et al., 2021; Yulia et al., 2020). Based on this, there is a need for innovation in the form of developing a learning program based on multiple representations integrated with PjBL STEM to foster students' sustainability literacy (Ghorbani et al., 2011), students are expected to have sustainability literacy (Campbell et al., 2021; Lund, 2007; Russel et al., 2021; Serpa & Sá, 2018) in facing global challenges and problems faced in the future.

Even though the implementation of the STEM approach based on multiple representations by exploring local potential is very important to be applied to foster sustainability literacy in physics learning, currently in Indonesia there has not been much learning developed with this approach, especially on the topic of renewable energy (Azzahra et al., 2022; Desnita, 2015; Dinantika et al., 2019; Nugroho et al., 2019; Putri et al., 2019). Research conducted by Azzahra et al (2022) developing e-modules on renewable energy sources but using the SETS approach besides that learning activities only focus on cognitive aspects while psychomotor and affective aspects are not prominent. Whereas Desnita (2015) developing an environment-based curriculum on renewable energy material but not aimed at fostering students' sustainability literacy. On research Dinantika et al. (2019) and Putri et al. (2019), both apply models to renewable energy material but Dinantika et al.'s research (2019) focuses on measuring the effect of the developed model on student creativity and Putri et al's research (2019) focuses on the effect of applying the model to student learning outcomes. Research conducted Nugroho et al. (2019) only limited to reviewing the STEM approach based on local wisdom to increase sustainability literacy but not developing learning programs. Thus it have been done study to develop a learning program based on PjBL George Lucas and STEM integrated multiple representations to foster students' sustainability literacy.

Methods

This research was conducted at SMAN 2 Kotabumi, the subjects in this study were students of SMA Negeri 2 Kotabumi class XI MIPA, totaling 3 classes and 2 classes were taken as samples by means of purposive sampling.Namely choosing cases with the same/equivalent academic profile. This study uses mixed methods with the ADDIE Research and Development model (Analysis, Design, Develop,

Implementation and Evaluation) by Robert Marie Branch, as shown in the following figure:

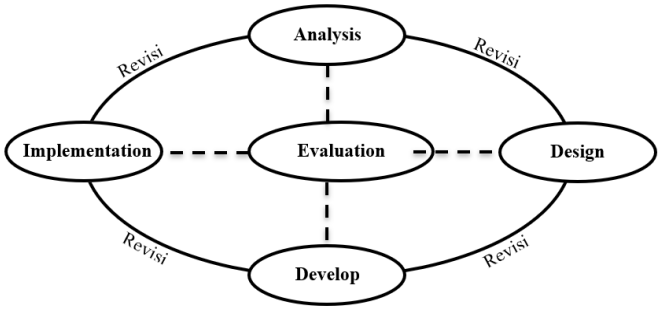

Figure 1. The ADDIE concept (Branch, 2010).

The application that researchers use to develop products (RPP, e-handout LKPD and comics) as teaching materials is Canva.
The following describes the stages of the research conducted.

1. Analysis Stage (Analysis)

At this stage an analysis of teacher needs is carried out to obtain in-depth initial information regarding renewable energy physics learning, learning difficulties, media, methods, teaching materials used, learning objectives and competencies expected by students after studying Renewable Energy material and problems that arise in the activity process teaching and learning in the field, then collecting possibilities and solutions that can be used to overcome existing problems. Data collection techniques using Google Forms. Respondents were taken based on their willingness to fill out the Google form. Data analysis from the results of the questionnaire is described in percentage form, then interpreted qualitatively.

In addition, a lattice analysis of sustainability literacy measurement instruments was also carried out through literature studies (article studies). Then an analysis of multi-representation, PjBL, and STEM learning process variables (implementation protocol checklist) is carried out through articles or literature reviews.

In addition, an analysis of students was carried out by holding pretests in 3 classes (classes XI MIPA 1, XI MIPA 2 and XI MIPA 3) to choose experimental and control classes.

2. Design Stage (Design)

From the analysis of needs found by researchers to:

a. Formulation of learning objectives, preparation of RPP structural framework, e-handouts, LKPD, learning comics to foster student sustainability literacy based on integrated multiple representation PjBL George Lucas and STEM
b. Determination of the systematic presentation of material, illustrations, and visualization.

Writing initial drafts of RPP products, e-handouts, LKPD and learning comics based on multiple representation integrated PjBL STEM which contain attractive covers, development of material concepts, interesting images related to the material. At this early stage the researcher also made practicum instruments for students and educators, product validation instruments, and test questions instruments.

Furthermore, the instrument will be validated by 2 lecturers with doctoral degrees and 1 physics educator with the minimum criteria for a master's degree. The product

is designed based on the results of theoretical studies and studies of previous research results on lesson plans, e handouts, worksheets and effective learning comics. The next product design follows a multi-representational grid, PjBL and STEM instruments/indicators to encourage sustainability literacy. The validity instrument used was a Likert scale questionnaire with five choices, namely (1) not feasible, (2) less eligible, (3) feasible, (4) very feasible.

Validity data analysis

The product validity of the research results was assessed by 3 expert validators. The activities carried out in the validity data analysis process are as follows:

1. Qualitative assessment of learning device development products is carried out through a checklist assessment. The results of the assessment from the validator in the form of product quality are coded on a qualitative scale then the qualitative value is changed to a quantitative value with the conditions as in Table

Table. changing Qualitative Values into Quantitative Values

Mark	Number
Very feasible	4
Feasible	3
Less Eligible	2
Not Feasible	1

Akker (1999)

2. Recapitulate the results of the expert assessment into a table which includes aspects of the assessment ($\overline{Ai}$) and the total score ($\overline{Vij}$) for each validator
3. Determine the average value of the validation results from all validators for each criterion with the formula:

$$\overline{Ki} = \frac{\sum_{j=1}^{n} \overline{Vij}}{n}$$

Information:
$\overline{Ki}$= average criterion i
$\overline{Vij}$= the value of the assessment results of the I-th criterion by the j-validator
n = the number of validators

1. Determine the average value for each aspect with the formula:

$$\overline{Ai} = \frac{\sum_{j=1}^{n} \overline{Kij}}{n}$$

Information:
$\overline{Ai}$= average value for the i-th aspect
$\overline{Kij}$= average for the ith aspect of the jth criterion
n = the number of criteria

2. Find the total average ($\overline{Va}$) with the formula:

$$\overline{Va} = \frac{\sum_{i=1}^{n} \overline{Ai}}{n}$$

Information:
$\overline{Va}$= total average
$\overline{Ai}$= average for the i-th aspect

n = number of aspects

1.1 Determine the validity category of each criterion ($\overline{Kij}$) or the average aspect (Ai) or the total average ($\overline{Va}$) with the validation categories that have been set as shown in Table 2.

Table 2. Value Validity Criteria

Mark	Criteria
3,5 ≤ V ≤ 4	Very Valid
2,5 ≤ V ≤ 3,5	Valid
1,5 ≤ V ≤ 2,5	Valid Enough
0 ≤ V ≤ 1,5	Invalid

Nieveen (1999)

A learning device is said to be valid if the results obtained are within the range (2.5 ≤ V < 3.5) and can be tested in the field.

3. Development Stage (Develop)

After further validation, the e-handout and e-LKPD product designs will be improved according to the validator's suggestions. The development stage carried out begins with the development of a sustainability literacy measurement instrument. This instrument was tested on students who had studied Renewable Energy to get the reliability of the questions. Furthermore, questions with high reliability can be used as pretest and posttest questions in the control and experimental classes.

4. Implementation Stage

At the implementation stage experimental research was carried out with a quantitative design in the form of a quasi-experimental method "Non-equivalent Pretest - Posttest Control Group Design".

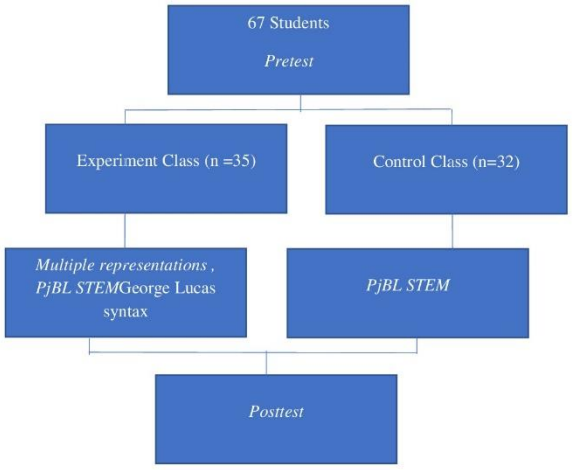

Figure 2. *Learning Program Implementation Stage*

Furthermore, trials were carried out in the experimental group and the control group. The experimental group (Class XI MIPA 3) used a learning program based on multi-representation integrated PjBL George Lucas and STEM while the control group (XI MIPA 2) used the PjBL STEM approach only. The trial or implementation stage was carried out on a limited basis at SMAN 2 Kotabumi to find out the effectiveness of lesson plans, e-handouts, worksheets, learning comics based multi-representation integrated PjBL STEM to foster student sustainability literacy. There are several stages in the implementation of this product, namely the first step is to conduct trials using lesson plans, e-handouts and worksheets for students to find out the practicality of e-handouts and worksheets that have been developed using attractiveness and legibility instruments. The second step is to test the effectiveness of the e-handout and LKPD, namely using a test instrument using the Google form. This implementation serves to determine student sustainability literacy. To see the effectiveness of the questions, namely using the SPSS program.

5. Evaluation Stage (Evaluate)

At this evaluation stage, researchers evaluate the e-handouts and e-LKPD that have been developed which aim to determine the practicality and effectiveness of e-handouts and e-LKPD on students' continuing literacy after learning using e-handouts and e-LKPD. e-LKPD on renewable energy topics/materials. The data described are

a. Data were obtained from student response questionnaires after using the e-handout and e-LKPD as well as posttest data on student sustainability literacy. After the lesson the teacher gave a student response questionnaire after learning about the use of the e-handout and e-LKPD that the researcher gave.
b. Test the effectiveness of e-handout and e-LKPD
c. In this study, testing was carried out using the Google Form, the results of which were analyzed using SPSS. The material used is renewable energy material according to the e-handout and e-LKPD products that have been developed.
d. Reflection on learning, regarding how students feel after learning renewable energy material, what has been good in learning and what needs to be improved for further renewable energy learning.

Research instruments such as: observation sheet, and test results of learning.

a. Teacher needs analysis using google form developed by the researchers themselves. The instrument that the Lampung teacher will fill online is to obtain detailed information about the learning process that has been going on so far whether PjBL STEM education is oriented, multiple representation.
b. Sheet Observations developed in the form of observation sheets on student activities during the implementation learning programs bsaed on multiple representation integrated PjBL STEM to foster student sustainability literacy on the topic of renewable energy. The observation sheet will contain a list of student activities.
c. Student sustainability literacy test instruments/questions.
d. A standardized test to measure student sustainability literacy developed by researchers through a grid of sustainability literacy instruments/indicators from literature studies.

Research data analysis techniques will be carried out as follows.

1. An inductive qualitative approach is used to analyze qualitative data. Data will be organized categorically and chronologically, reviewed iteratively, and coded.
2. Quantitative data processing in the form of analysis of student sustainability literacy data is based on the normalized gain score (N-gain). which can be described as follows:

N gain	Criteria
g > 0,7	High
0,3 ≤ g≤ 0,7	Medium
9 < 0,3	Low

Qualitative assessment of current sustainability literacy observations
the application of STEM-based multiple representation-based learning is carried out through tests.

Based on the grid of sustainability literacy measurement instruments, 20 sustainability literacy questions were made on the knowledge dimension, 3 skills dimension questions, 4 attitude dimension questions and 9 behavior dimension questions. The test results were then analyzed using SPSS 26. The processing of this quantitative research data begins with statistical tests in the form of normality tests and homogeneity tests, as follows:

a) Normality test using the One Sample Kolmogorov-Smirnov Test using SPSS for windows version 26.
b) Wilcoxon test

The research procedure can be seen in Figure 3 below:

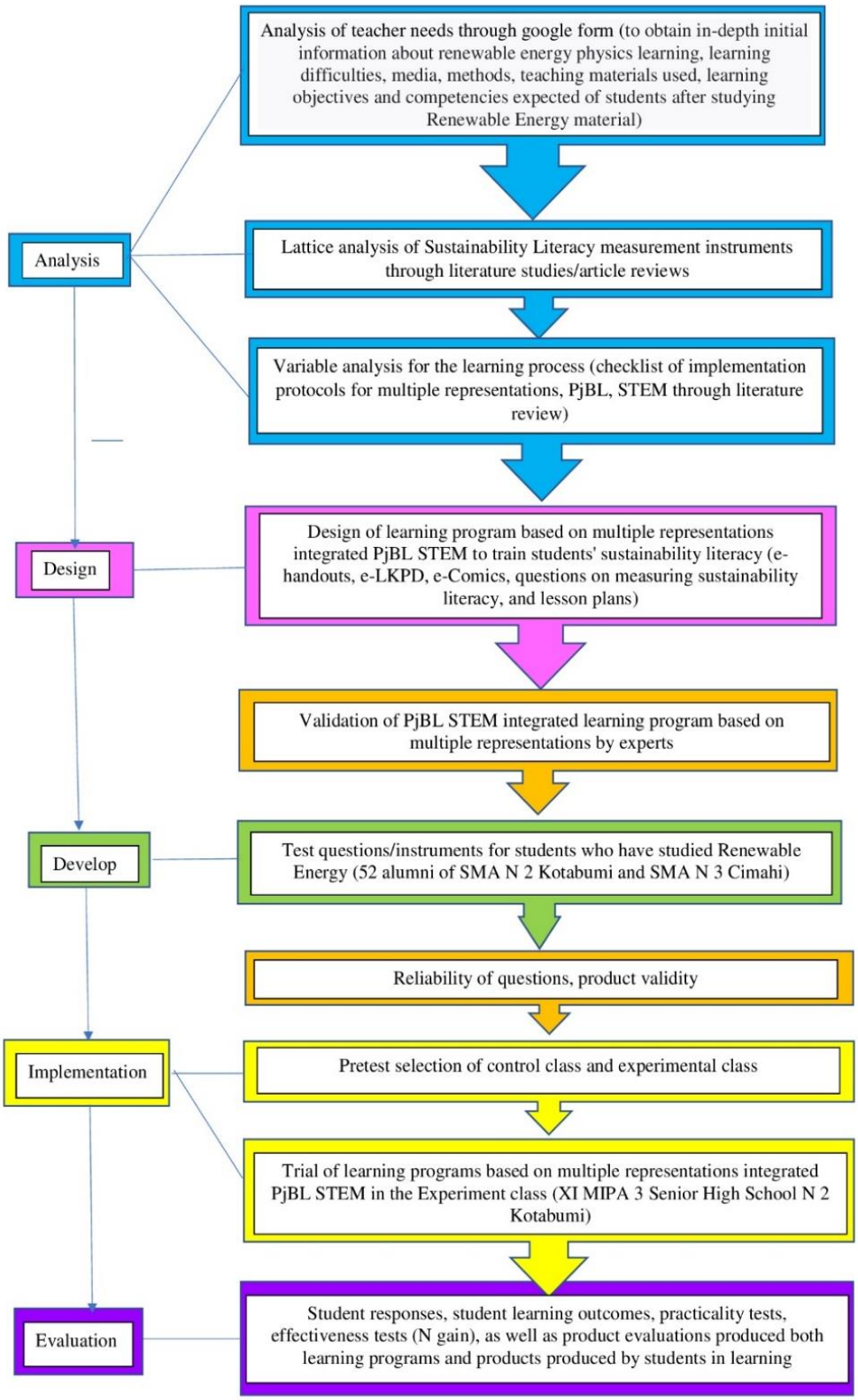

Figure 3. Research procedure

RESULTS AND DISCUSSION

The results of research on the development of this learning program are; (1) questions about measuring sustainability literacy according to the instrument grid; (2) creating e-handouts using the IF SO framework that displays various learning formats (content differentiation) in the form of text, images, videos and others as shown in Figure 4;

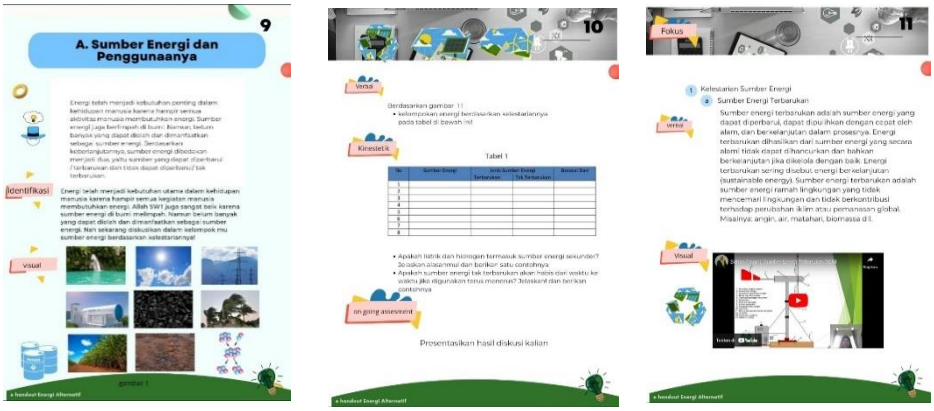

Figure 4. e-handout with the IF-SO framework

(3) creation of the PjBL e-LKPD as a project guideline for the manufacture of bioethanol/briquettes (renewable energy) with integrated STEM which results in product differentiation with different learning processes, as shown in the figure;

Figure 5. e-LKPD integrated STEM PjBL

(4) making e-comics in everyday language with attractive images that represent content differentiation as shown in figure 6;

Figure 6.e-Comic (One of Multi Representation Learning)

The results of the research show that the product developed is a very valid learning program based on expert judgment. The product meets the valid characteristics in terms of the construct validation results of the learning program (RPP, e-handout, e-LKPD, and e-Comic) obtained an average total value of 4 with 100% construct assessment criteria or with a very valid category. Construct validation shows the internal consistency between the components of the model, namely (1) syntax, (2) social system, (3) principle of reaction, (4) support system and (5) impact of instructional accompaniment. This can be seen from the e-handouts, e-LKPD and e-Comics which are made based on multiple representations which facilitate the learning needs of students both verbally and visually with various pictures, graphics, text, videos and others. In addition, the learning program also makes students actively learn to construct their knowledge together by carrying out projects for making renewable energy according to local potential, the learning program also improves students' ability to communicate as seen from students being able to communicate their learning outcomes both verbally, visually using PPT, Canva, posters and others. For content validation the total average is 3.92 with a validity criterion of 97.63% or a very valid category. This can be seen from the identity of the RPP, the main components of the RPP, the steps for presenting the LKPD which present material content sequentially and completely in presenting material in the form of theory.

The learning program was then tested on students of class XI MIPA 3 at SMAN 2 Kotabumi. The number of students in the class is 35 people consisting of 24 female students and 11 male students.

A detailed description of the activities at each meeting uses the PjBL George Lucas syntax as follows:

Stage 1 Determination of Fundamental Questions

a. Students observe videos/E-handout/e-LKPD/e-Comics

Studying the same content in different formats is learning based on multiple representations. This learning is also one of the differentiation learning that is currently being promoted by the government, namely content differentiation.

Renewable energy material is presented in various formats, namely by e-handout which contains videos, tables, diagrams, pictures and others, e-LKPD which is designed by utilizing local wisdom, as well as using e-Comics that use everyday language. including one of the multi-representation-based learning that facilitates the various needs of students in learning.

Figure 7. Based Learning*Multiple Representations*

At this learning stage students watch videos about the limitations of energy and renewable energy sources, e-handouts, e-LKPD and e-Comics.

b. Based on the problems in the video the teacher asks what solutions students can do to overcome energy limitations?

Phase 2 preparing a project plan (design project)

Figure 8. Students Collaborating to Arrange Schedules and More

The learning program developed makes students work together in planning projects, students also observe the local potential around them. Learning that links what is learned with the surrounding environment, including STEM-based learning.

Phase 3. Schedule Preparation Phase

students are trained to be responsible for completing projects on their own schedule.

Phase 4 Monitoring Students in Project Progress

Figure 9. The teacher gives directions regarding the project to be implemented

The learning activities in Figure 9 show the teacher as a facilitator in learning. Where the teacher guides learning so that students are actively involved so that learning activities run smoothly according to the learning objectives that have been set.

Figure 10.Students make bioethanol/briquettes

The student activity in the picture shows that students have been able to make alternative energy, namely bioethanol/briquettes, thus it can be said that the above learning activities train and grow students' sustainability literacy.

Phase 5. Outcome Assessment

One indicator of learning success/achievement of the expected learning objectives is to assess learning outcomes, in this case students are said to have succeeded in cultivating sustainability literacy because the results of the N gain value for the experimental class are higher than the control class.

a) Dimensions of Sustainability Literacy Knowledge

Table 1. Results of One Sample Kolmogorov-Smirnov Analysis

	Control Class		Experiment Class	
	Pretest	*Posttest*	*Pretest*	*Posttest*
N	32	32	35	35
Means	33,91	47,19	35,57	68,43
asymp. Sig (2 tailed)	0.001c	0.000c	0.016c	0.025c

Based on Table 1. the results of the Kolmogorov-Smirnov one sample output obtained a significance value (2 tailed) in the control class for the pretest of 0.001 and posttest 0.000 both less than 0.05 and a significance value (2 tailed) in the experimental class for the pretest of 0.016 less than 0.05 and the posttest of 0.025 is less than 0.05 which means that both the pretest and posttest data for the control and experimental classes are not normally distributed. So that the next test must use

nonparametric. Furthermore 2 relate sample tests (Wilcoxon) were carried out to see the increase in pretest and posttest to analyze the data and interpret the results.

Table 2. Ranks of Wilcoxon Analysis Results Pretest Posttest Sustainability Literacy Knowledge Dimension

	Control Class			Experiment Class		
	N	MeanRanking	Sum of Ranks	N	MeanRanking	Sum of Ranks
Negative Ranks	7a	7,71		4a	3.88	15.50
Positive Ranks	19b	15.53	297.00	30b	19,32	579.50
ties	6c			1c		
Total	32			35		

Based on Table 2. the positive ranks of the experimental class were greater than the control class, namely as many as 30 students experienced an increase, namely having a posttest score greater than the pretest value. Positive ranks or the difference between positive before and after variables as many as 30 observations or in other words there are 30 observations of literacy sustainability dimensions of knowledge after utilizing integrated PjBL STEM based learning more than observations before using integrated PjBL STEM based learning with an average ranking 19.32 with a positive rating of 579.50 . Positive ranks means that the experimental class has a higher posttest score than the pretest score. While the control class has lower positive ranks than the experimental class, which is 19 observations.

Table 3. Analysis Results*Wilcoxon Signed Ranks Test*

	Control Class	Experiment Class
	Posttest – Pretest	*Posttest – Pretest*
Z	-3.097b	- 4,826b
Asymp Sig(2 tailed)	0.002	0.000

Based on Table 3, it is obtained that the Z count is -3.097 and the asymp sig (2 tailed) control class is 0.002 <0.05 and the Z count is -4.826 and the asymp sig (2 tailed) is 0.000 <α (0.05), then reject H0 which means that there is a difference between the average pretest and posttest scores after students carry out learning using PJBL STEM in the control class and using learning programs based on integrated PjBL STEM in the experimental class.

Table 4.*N gain Literacy Sustainability Knowledge Dimension Class Control and Experiment*

No.	Class	*N Gains*	Criteria
1.	Control	0.180	Low
2.	Experiment	0.489	Medium

Table 4 shows that the average N gain for the experimental class is 0.489 indicating medium criteria, while the average N gain for the control class is 0.180 indicating low criteria. The experimental class has an average N gain higher than the average N gain in the control class so that it can be said that the use of an integrated PJBL STEM learning program based on multiple representations is better than PjBL STEM learning alone in increasing the sustainability of student literacy in the knowledge dimension.

b) Literacy Sustainability Skills Competency Dimensions

Table1. Analysis Results*One sample Kolmogorov-Smirnov*

	Control Class		**Experiment Class**	
	Pretest	***Postest***	***Pretest***	***Postest***
N	32	32	35	35
Means	42.97	53,91	40,71	82,14
asymp. Sig (2 tailed)	0.000c	0.000c	0.000c	0.000c

Based on Table 5 the results of the Kolmogorov-Smirnov one sample output obtained a significance value (2 tailed) for the control class pretest 0.000 and posttest 0.000, the experimental class asymp sig (2 tailed) pretest of 0.000 less than 0.05 and posttest of 0.000 less than 0, 05 which means that the four data, both pretest and posttest, are not normally distributed. So that the next test must use nonparametric. Furthermore2 relate sample tests (Wilcoxon) were carried out to see the increase in pretest and posttest to analyze the data and interpret the results.

Table2.*Wilcoxon Analysis Results Ranks (Pretest Posttest Literacy Sustainability Dimensions Skills/Competencies)*

	Control Class			Experiment Class		
	N	*MeanRanking*	*Sum of Ranks*	N	*MeanRanking*	*Sum of ranks*
Negative Ranks	4a	8.00	32.00	0a	0.00	0.00
Positive Ranks	14b	9.93	139.00	29b	15.00	435.00
ties	14c			6c		

Total	32	35

Based on Table 6. the positive ranks of the experimental class were greater than the control class, namely as many as 29 students experienced an increase, namely having a posttest score greater than the pretest value. Positive ranks or the difference between positive before and after variables as many as 29 observations or in other words there are 29 observations of sustainability literacy dimensions of renewable energy skills/competencies after utilizing integrated PjBL STEM based learning more than prior observations using integrated multiple representations based learning STEM PjBL with average ranking of 15.00 with a number of positive ratings of 435.00. Positive ranks means that the experimental class has a posttest score higher than the pretest score and is better than the control class which only increased by 14 observations.

Table3. Analysis Results *Wilcoxon Signed Ranks Test*

	Control Class	Experiment Class
	Posttest- Pretest	*Posttest – Pretest*
Z	-2.502b	- 4,798b
Asymp Sig (2 tailed)	0.012	0.000

Based on Table 7, it is obtained that the Z count of the control class is -2.502 and the asymp sig (2 tailed) is 0.012 and the experimental class with the Z count is -4.798 and the asymp sig (2 tailed) 0.000 < α (0.05), then reject H0 which means that there is a difference between the average pretest and posttest scores after students carry out learning using either PjBL STEM or using integrated PjBL STEM based learning programs.

Table4.*N gain Experimental Class and Control Class Sustainability Literacy Skill/ Competency Dimension*

No.	Class	*N Gains*	Criteria
1.	Control	0.193	Low
2.	Experiment	0.681	Medium

In Table 8 it can be seen that the average N gain of the experimental class is 0.681 indicating medium criteria while the average N gain of the control class is 0.193 indicating low criteria. The experimental class has an average N gain higher than the average N gain in the control class so that it can be said that the use of integrated PJBL STEM learning programs based on multiple representations is better than PjBL

STEM learning alone in increasing students' sustainability literacy in the skill/competence dimension.

a) Dimensions of Sustainability Literacy Attitudes

Table 9. Analysis Results*One sample Kolmogorov-Smirnov*

	Control Class		**Experiment Class**	
	Pretest	*Posttest*	*Pretest*	*Posttest*
N	32	32	35	35
Means	40,63	61,72	55.00	80.00
asymp. Sig (2 tailed)		0.000c	0.000c	0.000c

Based on the results of the Kolmogorov-Smirnov one sample output, a significance value (2 tailed) was obtained for the control class of 0.000 pretest and 0.000 posttest and for the experimental class the pretest was 0.000 less than 0.05 and the posttest was 0.000 less than 0.05 which means that the four data are not normally distributed . So that the next test must use nonparametric.

Furthermore2 relate sample tests (Wilcoxon) were carried out to see the increase in pretest and posttest to analyze the data and interpret the results.

Table 10.*Wilcoxon Analysis Results Ranks (Pretest Posttest Literacy Sustainability Attitude Dimension)*

	Control Class			**Experiment Class**		
	N	*MeanRanking*	*Sum of Ranks*	N	*MeanRanking*	*Sum of ranks*
Negative Ranks	3a	8.50	25.50	3a	10.33	31.00
Positive Ranks	20b	12.53	250.50	23b	13.91	320.00
ties	9c			9c		
Total	32			35		

Based on Table 10, the positive ranks of the experimental class were larger than the control class, namely as many as 23 students experienced an increase, namely having a posttest score greater than the pretest score. Positive ranks or the difference between positive before and after variables as many as 23 observations or in other words there are 23 observations of sustainability literacy dimensions of

attitude after utilizing integrated PjBL STEM based learning more than the observation before using integrated PjBL STEM based learning with an average ranking 13.91 with a positive rating of 320.00 . Positive ranks means that the experimental class has a posttest score higher than the pretest score and better than the control class which only increased by 20 observations.

Table 11. Analysis Results *Wilcoxon Signed Ranks Test*

	Control Class ***Posttest- Pretest***	**Experiment Class** ***Posttest – Pretest***
Z	-3,569	- 3,748b
Asymp Sig (2 tailed)	0.000	0.000

Based on Table 11, it was obtained that the Z count of the control class was 3.569 with an asymp sig of 0.000 and the experimental class with a Z count of -3.748 and asymp sig (2 tailed) 0.000 < α (0.05) , then reject Ho which means that there is a difference between the average pretest and posttest scores after students carry out learning using both PjBL STEM-based learning and PjBL STEM integrated multiple representations-based learning programs.

Table12. Average*N Gain Literacy Sustainability Attitude Dimension*

No.	Class	*N Gains*	Criteria
1.	Control	0.341	Medium
2.	Experiment	0.529	Medium

In Table 12, it appears that the average N gain of the experimental class is 0.529 indicating medium criteria while the average N gain of the control class is 0.341 indicating moderate criteria but smaller than the experimental class. The experimental class has an average N gain higher than the average N gain in the control class so that it can be said that the use of integrated PJBL STEM learning programs based on multiple representations is better than PjBL STEM learning alone in increasing students' sustainability literacy in the attitude dimension.

d) Behavioral Dimension Sustainability Literacy

Table 13. Analysis Results*One sample Kolmogorov-Smirnov*

Description	**Control Class**	**Experiment Class**

	Pretest	***Postest***	***Pretest***	***Postest***
N	32	32	35	35
Means	21,252	24,678	22,392	27,785
asymp. Sig (2 tailed)	0.116c	0.087c	0.069c	0.000c

Based on Table 13. the results of the one sample Kolmogorov-Smirnov output obtained a significance value (2 tailed) for the control class 0.116 pretest and 0.087 posttest which means the data is normally distributed while the pretest experimental class is 0.069 more than 0.05 which means the data is normally distributed and the posttest is 0.000 less than 0.05 which means the data is not normally distributed. So that the next test must use nonparametric.

Then a 2 relate sample (Wilcoxon) test was carried out to see the increase in pretest and posttest to analyze the data and interpret the results.

Table 14.*Wilcoxon Analysis Results Ranks (Pretest Posttest Literacy Sustainability Dimensions* Behavior)

	Control Class			**Experiment Class**		
	N	***MeanRanking***	***Sum of Ranks***	**N**	***MeanRanking***	***Sum of ranks***
Negative Ranks	9a	8,22	74.00	6a	12.00	72.00
Positive Ranks	23b	19.74	454.00	29b	19,24	558.00
Ties	0c			0c		
Total	32			35		

Based on Table 14. the positive ranks of the experimental class were greater than the control class, namely as many as 29 students experienced an increase, namely having a posttest score greater than the pretest value. *Positive ranks*or the difference between positive before and after variables as many as 29 observations or in other words there are 29 observations of sustainability literacy dimensions of behavior after utilizing integrated PjBL STEM based learning more than observations before using multiple representation based learning*ations*integrated PjBL STEM with an average rating of 19.24 with a total positive rating of 558.00. Positive ranks means that the experimental class has a posttest score higher than the pretest score and is better than the control class which only increased by 23 observations.

Table 15. Analysis Results*Wilcoxon Signed Ranks Test*

	Control Class	Experiment Class
	Posttest- Pretest	*Posttest – Pretest*
Z	-3.553b	- 3,980b
Asymp Sig (2 tailed)	0.000	0.000

Based on Table 15, it was obtained that the Z count of the control class was -3.553 with an asymp sig of 0.000 and the experimental class with a Z count of -3.980 and asymp sig (2 tailed) 0.000 < α (0.05), then reject H0 which means that there is a difference between the mean the average pretest and posttest scores after students carry out learning using either PjBL STEM-based learning or PjBL STEM integrated multiple representations-based learning programs.

Table 16. Average*N gain Literacy sustainability Behavior Dimension*

No.	Class	*N Gains*	Criteria
1.	Control	0.416	medium
2.	Experiment	0.839	High

Table 16 shows that the average N gain for the experimental class is 0.839 indicating high criteria, while the average N gain for the control class is 0.416 indicating medium criteria. The average N gain of the experimental class is greater than the average N gain of the control class so that it can be said that the use of integrated PJBL STEM learning programs based on multiple representations is better than STEM PjBL learning alone in increasing students' sustainability literacy in the behavioral dimension.

Phase 6 Experience Evaluation

Presentation on making briquettes/bioethanol

Figure 11. Students Presenting the Strengths and Weaknesses of Bioethanol Making Briquettes and Future Improvement Plans

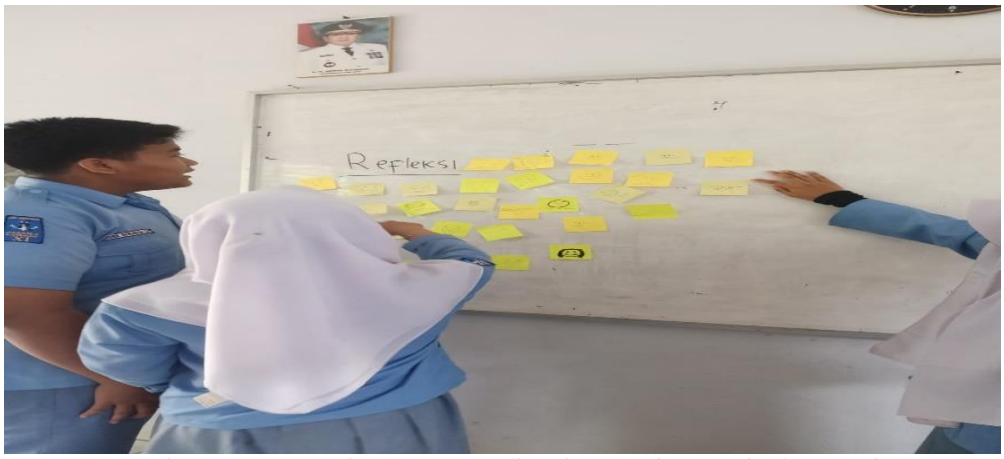

Figure 12. Students Do Reflection at the End of Learning

Reflection is an important part of learning where with reflection both teachers and students can find out what they have learned/mastered after learning, what needs to be corrected and improved, what is good and needs to be maintained, and how students feel after learning that is renewable. energy material.

Stage 6. Evaluation Stage (Evaluate)

The evaluation stage consists of evaluating the products made by students, namely bioethanol and student-made briquettes.

In addition to product evaluation, students carry out evaluations by working on 47 evaluation questions given by the teacher to measure students' sustainability literacy consisting of multiple choice questions and checklists.

Product Effectiveness

the learning program based on multi-representation integrated PjBL STEM has shown to be effective in use, as evidenced by the increased physics learning outcomes in the experimental class, which is better than the control class. The following is data on student learning outcomes in the experimental and control classes.

Table 17. Sustainability Literacy Results

Results	Control Class			Experiment Class		
	Means *Pretest*	Posttest means	*N gain*	Means Pretest	*Posttest means*	*N gain*
Knowledge Dimensions of Literacy Sustainability	33,91	47,19	0.180	35,57	68,43	0.489
Literacy Sustainability Skills/Compete	42.97	53,91	0.193	40,71	82,24	0.681

ncies Dimensions						
Dimensions of Sustainability Literacy Attitudes	40,63	61,72	0.341	55.00	80.00	0.529
Dimensions of Sustainability Literacy Behavior	21.25	24,67	0.419	22,392	27,785	0.839

Here's Figure 13to show Ngain Comparison of Control and Experiment Classes

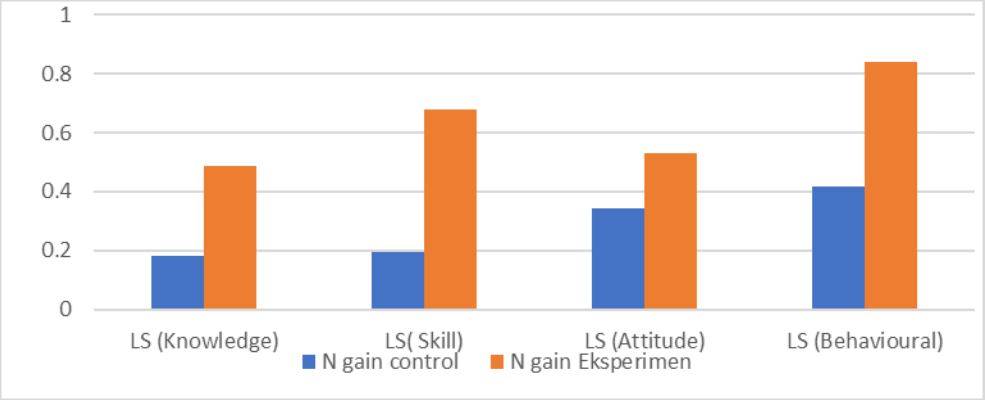

Figure 13.Comparison of Ngain Control and Experiment Classes

In addition, the effectiveness of the learning program can be seen from the increase in the acquisition of N literacy dimensions of knowledge, skills, attitudes and behavior in students.

the experimental class is higher than the control class.This is supported by student activities from start to finish, namely starting from students watching videos, studying content differentiation/multi-representation e-handouts, students carrying out activities in groups in learning the concept of renewable energy which is presented with several representations that contribute to sustainable literacy achievement because it is appropriate with multiple representation theory, which is a strategy that represents the same concept, but uses a variety of different formats to complement each other (Lusiyana et al., 2019). The format used can be a combination of text, animated images, tables, graphs, verbal, algebraic notation, and mathematical equations (Ainsworth, 1999).The effectiveness of the learning program is in accordance with what is saidAkker (1999)which states: "Effectiveness refers to the extent to which experience and results with an intervention are consistent with the intended purpose"

The table above shows just that product development meets the criteria of effectively increasing the average value of the experimental class is greater than the control class.As well as demonstrating an increase in student sustainability literacy in the knowledge dimension with indicators: (1) being able to classify various energy sources both renewable and non-renewable, (2) being able to understand the impact

if energy sources run out, (3) being able to show what actions can be taken to reduce/ provide an alternative in preventing running out of energy sources. The learning program increases students' sustainability literacy in the skills dimension, namely with the indicator of being able to make their own bioethanol/briquettes with teacher guidance, as shown in Figure 17. The following is

Figure 17. Students produce bioethanol

The learning program increases students' sustainability literacy in the attitude dimension with indicators showing a clear attitude (positive and negative) towards a given sustainability issue. Students started campaigning using posters to invite others to care about the problem of limited energy, as shown in Figure 18 below:

Figure 18. Students presenting posters

Based on research observations on the use of PjBL STEM integrated PjBL STEM-based learning programs on the topic of renewable energy that have been carried out by researchers, there are several things that can be used as research findings, including (1) learning is proven to maximize student potential and reduce learning gaps because through learning students with multiple representations can be further facilitated and develop their potential to the fullest because students with a visual learning style can learn through videos, pictures, and also see friends doing experiments themselves, for kinesthetic learning styles can listen to friends' presentations,and reinforcement by the teacher while students with kinesthetic learning styles can learn by working on the given project activities and presenting the results; (2) Learning activities can grow students to have sustainability literacy related to renewable energy, this is in accordance with what was stated by(Probst et al., 2019)namely (attitude of sustainability)/feeling of personal ability that influences a sustainable attitude where students have been able to make renewable energy and have an attitude of saving energy and presenting the results; (3) The development of learning programs carried out by the author is also in line with government policies in implementing the current curriculum where learning must be project-based, so that

the development of multi-representation-based learning programs integrated with PjBL STEM to foster student sustainability literacy on renewable energy topics is very appropriate. These results are similar to previous research that STEM learning approaches tend to increase student engagement in promoting literacy and deep understanding (Listiana et al., 2019)

CONCLUSION (5%)

Based on the analysis of research data and discussion of the development of a multiple representation-based learning program that is integrated with PjBL George Lucas and STEM, it can be concluded that the PjBL STEM integrated learning program is based on multiple representations developed describes the steps for developing a renewable energy learning program based on multiple representation integrated PjBL george Lucas and STEM to foster student sustainability literacy. This study uses mixed methods with the ADDIE R&D model. Development of an integrated PjBL STEM-based learning program, namely lesson plans with PJBL George Lucas and STEM syntax, e-handout multiple representations with the IF SO framework, PjBL STEM LKPD, comic strips on renewable energy in everyday language and posters. Before being used the learning program was first validated by 3 experts anddeclared feasible to be implemented based on the assessment of experts who fulfill the very valid category with an average construct validation score of 4 and an average content validation value of 3.92. Learning programs that have been validated are then tested onSMA N 2 Kotabumi students are class XI MIPA 3 (experimental class) and class XI MIPA 2 (control class). The results of the research show that the learning program developed is effective in increasing sustainability literacyseen from the increase in N literacy gains in the dimensions of knowledge (0.489), attitudes (0.529), skills (0.681) and behavior (0.839) in the experimental class which were higher than the control class, namely N literacy gains in the dimensions of knowledge (0.180), attitudes (0.341), skills (0.193) and behavior (0.419).It appears that the learning program developed is very good (high) at cultivating sustainability literacy on the behavioral dimension, good (medium) at training sustainability literacy on the skills, attitude and knowledge dimensions.

The learning program created increases literacy in the dimensions of knowledge, especially in question items 1,2,3,5,6,7,8,11,13,18 and 19, namely being able to distinguish renewable and non-renewable energy, how to save energy/efforts to reduce use of fossil fuel energy, factors causing the increase in energy demand, shortage of fossil fuels, excess of renewable energy local wisdom that can be used to make energy. This is the role of learning programs, especially e-handouts where the handouts presented with the IF SO framework contain all of this information. The learning program also increases literacy in the sustainability dimension of skills/competencies where students can easily make bioethanol and briquettes, this is supported by the LKPD which was developed based on the PjBL syntax of George Lucas and STEM. The learning program also increases literacy in the dimensions of attitude/attitude sustainability such as turning off lights, fans, air conditioners when not in use, students feel they have to do real things in their daily lives to solve energy problems and want to replace non-renewable energy with alternative/renewable energy. The learning program also increases literacy in the dimensions of behavioral dimensions such as choosing to walk rather than riding a motorbike for short distances so as not to use up a lot of gasoline, choosing products that use alternative fuels compared to regular/fossil fuels if the price is the same, always turning off the

faucet when not using it, always close the refrigerator immediately after opening, choose a lamp with a solar cell energy source rather than an electric energy lamp.

The research results show thatthe use of integrated multiple representations-based learning programs of PjBL STEM has proven to be effective with the increased physics learning outcomes of the experimental class which are better than the control class, this also shows an increase
students' sustainability literacy in the knowledge dimension with indicators: (1) can classify various sources of energy both renewable and non-renewable, (2) can understand the effects if energy sources run out, (3) can show what actions can be taken to reduce/give alternative in preventing running out of energy sources. The learning program increases students' sustainability literacy in the skill dimension, namely with the indicator being able to make their own bioethanol/briquettes with the guidance of the teacher. The learning program increases students' sustainability literacy in the attitude dimension with indicators showing a clear attitude (positive and negative) towards a given sustainability problem. Students started campaigning using posters to invite others to care about the problem of limited energy.
In addition, the effectiveness of the learning program can be seen from the increase in N gain spatial thinking skills and literacy dimensions of knowledge, skills, attitudes and behavior in the experimental class which is higher than the control class, this is supported by student activities starting from the initial activity to the end starting from students watch videos, study content-differentiated e-handouts/multi-representations, students carry out activities in groups in learning the concept of renewable energy which is presented with multiple representations which also contribute to the achievement of sustainability literacy.

Based on research observations on the use of PjBL STEM integrated PjBL STEM-based learning programs on the topic of renewable energy that has been carried out by researchers, there are several things that can be used as research findings, including (1) learning is proven to maximize the potential of students and minimize learning gaps (learning gaps) because through learning students with multiple representations can be more facilitated and develop their potential to the fullest because students with a visual learning style can learn through videos, pictures, and also see their friends doing experiments, for audio style they can listen to their friends' presentations, and reinforcement by the teacher while for students with learning styles kinesthetics can learn by doing the given project activities and presenting the results. (2) Learning activities can train students to have sustainability literacy related to renewable energy, this is in accordance with what was stated by(Probst et al., 2019)namely (sustainability attitudes)/feelings of personal ability that influence sustainable attitudes where students have been able to make renewable energy and have an attitude of saving energy and presenting the results. (3) The development of the learning program carried out by the author is also in line with government policy in implementing the current curriculum where learning must be project-based, so that the development of a learning program based on multiple representations integrated with PjBL STEM to foster students' sustainability literacy on the topic of renewable energy is very appropriate.

Based on the results of the research that has been done, the researchers provide an integrated learning program based on multi-representation PjBL STEM that can be developed for other renewable energy materials such as PLTMh, PLTB, PLTS, etc. The PjBL STEM integrated learning program based on multiple

representations must be integrated with KSE (social-emotional competence) integrated differentiation learning in accordance with current government policies.

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