Bubungan Tinggi: Jurnal Pengabdian Masyarakat
http://ppjp.ulm.ac.id/journals/index.php/btj/index
e-ISSN: 2722-3043 p-ISSN: 2722-2934
Vol 7 No 1 2025
DOI: https://doi.org/10.20527/btjpm.v7i1.11349

Training on Lesson Plan of Climate Change STEM Project in the Physics Learning for Sustainable Development

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Article Info

Article history:
Received: September 10, 2024
Accepted: October 18, 2024
Published: January 27, 2025

Keywords:
Climate change
STEM project
Sustainable development

Abstract

Climate change education holds great potential but often fails to raise sufficient awareness of climate-related disasters. Students need localized, STEM-based learning to build adaptation strategies and eco-friendly lifestyles. This article focuses on improving students' understanding of physics concepts, problem-solving, and critical and creative thinking, aligning with the SDGs and Merdeka Curriculum goals. Using the Participatory Action Research (PAR) method, training activities involved observation, reflection, planning, action, and evaluation stages. Needs analysis discussions with teachers from Nganjuk Regency's MGMP informed the program. Training included STEM-based project learning focused on climate change and engaging physics and science teachers. Questionnaire analysis showed high enthusiasm for the program, as it integrated STEM with real-world climate issues, making learning relevant and motivating. This innovative approach fostered critical thinking and problem-solving while enhancing awareness and responsibility toward climate challenges. By connecting education to sustainability, the program encouraged students to develop eco-friendly solutions and actively participate in addressing global issues, preparing them to become agents of change.

To cite this article: Lestari, N. A., Jatmiko, B., Dwikoranto, D., & Prahani, B. K. (2025). Training on lesson plan of climate change stem project in the physics learning for sustainable development. *Bubungan Tinggi: Jurnal Pengabdian Masyarakat*, *7*(1), 205-221.

INTRODUCTION

In the past two years, several areas in East Java have experienced local disasters caused by climate change. In particular, coastal and highland areas are more vulnerable to disasters such as tidal floods (caused by rising sea levels) and landslides. Sawahan, Nganjuk, is an area that experienced landslides preceded by soil cracks and movement. A common cause of landslides is the rise of groundwater triggered by heavy rainfall. According to a researcher from the Geotechnology Research Center at the Indonesian Institute of Sciences (*Peneliti Pusat Peneliti Geoteknologi Lembaga Ilmu Pengetahuan Indonesia* or *LIPI*) (In Kumparan, 2017), soil movement occurs due to prolonged periods of high rainfall. The increased rainfall raises groundwater levels, reducing soil strength, which in turn causes the ground to move slowly.

Based on observations through interviews with residents around Petungulung Village, Margopatut, Sawahan District, and Nganjuk Regency, the ground had cracks measuring approximately 200 meters long and around 10 centimeters wide. These cracks pose a significant risk of landslides, leading to residents' concerns. The regional *BMKG* (Meteorology, Climatology, and Geophysics Agency) assisted by installing detection equipment that indicates potential landslides caused by soil cracks. Figures 1 document the results of these observations, showing the soil cracks in the Sawahan area of Nganjuk Regency.

(a) (b)

Figure 1 (a) Soil cracks in Sawahan Nganjuk and (b) Cracked soil detection tool in Sawahan, Nganjuk

There remains a potential for further soil movement, particularly as rainfall levels continue to be high. Therefore, educating residents about disaster mitigation is essential to improving their preparedness. As Chotimah (2019) pointed out, community knowledge positively affects disaster preparedness. Disaster mitigation education can be implemented in schools, especially in disaster-prone areas such as Sawahan and Nganjuk Regency. The aim is to develop adaptive strategies and foster disaster preparedness attitudes through contextual learning.

Natural phenomena resulting from climate change, like those occurring in the Nganjuk area, provide contextual problems that can be integrated into school learning processes. Contextual learning can be implemented by connecting the material the teacher teaches to real-world situations, encouraging students to relate their knowledge to its practical applications in daily life (Afriani, 2018). Project-based learning is an instructional design that can be used to combine physics concepts with real-world situations or problems relevant to students' lives (Santyasa, 2020). The aim is to enhance students' understanding of physics concepts, problem-solving abilities, and critical and creative thinking skills.

The project taught to students was expected to accommodate the need to develop abilities and skills in achieving the SDGs (Sustainable Development Goals) as outlined in the physics learning objectives of the Merdeka Curriculum. The sustainability aspect served as a target to be achieved during the learning process, making it more qualified and meaningful (meaningful learning) (Purnomo, 2023). STEM (Science, Technology, Engineering, and Mathematics) project-based physics learning presented a holistic and interactive approach to education, helping learners develop a deeper understanding and relevant skills for sustainable development (Nazhifah, 2023).

In addition to referencing the natural phenomena that require problem-solving, local potential in the region must be studied more deeply, particularly those relevant to learning. Nganjuk was called the "City of Winds" because of its windy characteristics. The potential of natural resources in Nganjuk could also be used as inspiration for creating projects, especially in learning physics. The design of these learning projects needed to be well-planned and adapted to the environment's needs to achieve their sustainability component. Therefore, based on the situation analysis results in the Nganjuk region, training and mentoring were planned to maximize the contribution of educators in implementing STEM project learning through the use of phenomena and regional potential in the Nganjuk Regency.

Based on the results of problem identification, the priority issues agreed upon for resolution during the program implementation were determined. These included the need to increase teachers' contributions in designing STEM project-based physics learning to support sustainable development (Utami, 2020) and the need to enhance knowledge of regional phenomena and potential, applying this knowledge in the form of STEM projects.

The researchers were enthusiastic about conducting this study because no training had been provided on STEM project implementation. Appropriate training could empower teachers to design innovative and relevant learning experiences, enhancing students' abilities to face sustainable development challenges.

This research aimed to explore the specific needs of teachers in designing STEM projects and to identify effective strategies for improving their knowledge and skills. With a holistic approach that considered the local context, the resulting STEM projects were expected to educate and contribute to awareness and action on sustainability issues within the community, positively impacting teachers, students, and the community.

The solution offered in this activity was to provide training and mentoring to physics teachers in Nganjuk Regency through the inspiration of STEM project learning in materials related to climate change. STEM project learning was chosen because it focused on integration across various disciplinary and transdisciplinary levels (Figure 2). This aligned with the character of the Merdeka Belajar Curriculum, which required the integration of competencies and the cultivation of the Pancasila Learner Profile through projects. The Pancasila Learner Profile was applied through contextualized project-based learning and interaction with the surrounding environment (GTK Kemendikbud, 2021).

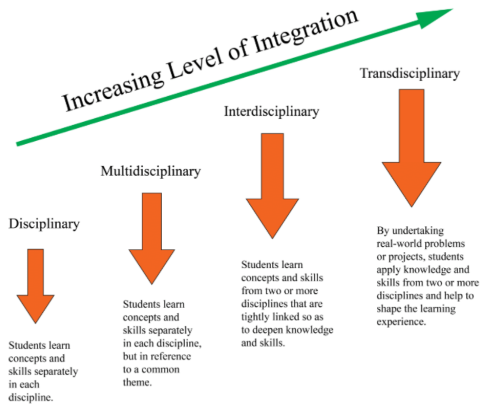


Figure 2 Level of integration of STEM education
(Source: SEAMEO Regional Centre for QITEP in Mathematics, 2021)

The project learning design in the *Merdeka Belajar* curriculum that will be exemplified uses a STEM approach. The chosen theme was Global Climate Change. Although climate disasters have occurred recently, not everyone knows their impact. Therefore, integrating natural disaster mitigation into the learning process with the Global Climate Change theme was necessary to ensure that future generations can live sustainably, aligning with the goals of the SDGs.

So far, climate change learning materials taught in schools have remained largely theoretical or textual. Due to the lack of contextualization, public awareness of climate disasters has stayed relatively low. It is crucial to demonstrate climate change adaptation to students, enabling them to adopt environmentally friendly lifestyles in their everyday activities. To change community behavior, schools, as key educators, need to incorporate climate disaster mitigation into their teaching materials. Climate change can be examined from multiple perspectives, including natural, social sciences, and religion. This multidimensional approach could be an excellent topic for a collaborative project among teachers from various subjects, applied to the same group of learners, integrating joint learning and assessment.

The solution proposed in this activity involves providing education on local natural phenomena and resources and equipping teachers with the necessary skills to develop STEM project-based learning plans.

METHOD

The method applied in this research was using learning technology and alternative learning product procurement technology to address problems that arose among teachers, specifically through the participatory action research (PAR) approach. PAR is a research approach that embodies an emancipatory agenda and seeks to work with community members as co-researchers in building knowledge and guiding change. The stages of research using the PAR method included observation, reflection, strategic action planning, action, and evaluation of research results. The activity began with a discussion between the proposing team and partners to identify the root of the agreed-upon priority problems and to determine the appropriate solution. Based on the results of these discussions, the team developed the training activities, covering both material and technical aspects of implementation. Figure 3 illustrates the flow of the action method and shows the mechanism for executing this student creativity program (*PKM*).

Figure 3 Flow of the method

To improve responsiveness to ongoing disasters, the proposer and partners agreed that the most feasible solution was to provide training in preparing STEM project lesson plans to support Education for Sustainable Development. This took the form of in-service activities held in Sawahan, Nganjuk Regency. A participatory approach was utilized in implementing the student creativity program activities, with the proposing team and partners actively involved in each activity. The diverse environmental conditions around the school had the potential to serve as a source of contextual learning media. Through the use of simple technology and a bit of creativity, innovative lesson plans could be developed that meet the needs of both teachers and students in the schools.

The first stage in implementing the activity was a needs analysis discussion involving the team and teachers at the school where the training was held, namely in Nganjuk Regency. The team developed a training program with materials and technical implementation in the next stage. The following stage involved the actual implementation, which consisted of conducting training on STEM project learning planning. The training occurred on August 10, 2024, at SMA Negeri 1 Nganjuk. To facilitate students' understanding of climate change events that had been presented textually, teachers could invite students to explore events in the environment through projects and seek information from various sources on climate change. The training on joint project learning planning in the implementation of the independent learning curriculum was delivered to the trainees in the following sequence of materials and/or activities:

1. Overview of Physics Learning Innovation
2. Climate Change ESD
3. STEM Project-based Learning
4. STEM Project Learning Planning Inspiration
5. Group formation to develop lesson plans and plan STEM project designs based on agreed topics.
6. The PKM team of the Physics Education Study Program FMIPA Unesa reports trainees' progress and provides feedback.
7. Revision by trainees based on input/suggestions by the *PKM* team as resource persons and validators.
8. Collection of lesson plans and joint project plans that have been prepared.
9. Joint reflection and evaluation.

Related to the inspiration for STEM projects that could be created, the following examples are provided:

1. Soil Crack Detection Tool

The phenomenon of cracked soil in one area of Nganjuk Regency inspired the design of an alarm project to detect soil cracks with the potential for landslides. The project design drawing is as follows (see Figure 4).

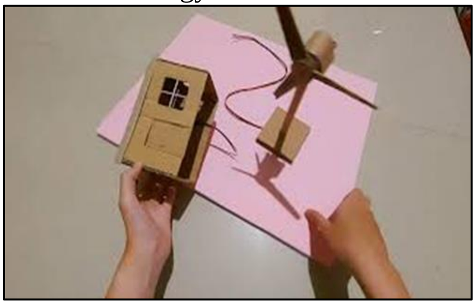
The STEM aspects that could be analyzed from the project included:

Science	: Electrical circuit preparation material
Technology	: The resulting tool
Engineering	: Design and placement of required components
Mathematics	: Measurement of component composition such as battery capacity size, measurement of voltage, current, and resistance requirements.

Figure 4 Simple soil crack detection device project

2. Wind Power Plant

The project design drawings were as follows (see Figure 5), referring to observing the windy potential in the Nganjuk area, which could be utilized as a power plant or alternative renewable energy source.



The STEM aspects that could be analyzed from the project included:

Science	: Alternative energy (renewable energy)
Technology	: Windmill Product
Engineering	: Windmill design
Mathematics	: Measure windmill components, power requirements, voltage, current, and resistance.

Figure 5 Windmill project as a power plant

The activities began with justifying the problems and needs of physics teachers in carrying out learning, especially in Nganjuk Regency. The method of implementing problem justification involved visiting higher schools in the Nganjuk area and conducting interviews with physics teachers.

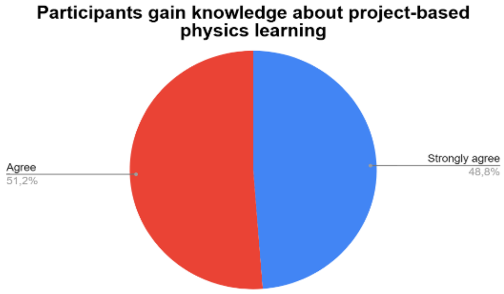
Data collection on the responses of training participants was presented in a questionnaire, along with assignments given at the end of the material delivery during the Training on the Preparation of STEM Project Learning Plans in Climate Change Material on the Implementation of ESD in Schools.

In the core activities, introductory material was presented, followed by a question-and-answer session. Then, the questionnaire was distributed to students. The results of the questionnaires filled out by the training participants of the STEM Project Learning Plan Preparation Training in Climate Change Material on the Implementation of ESD in Schools were presented as pie charts for each question and bar charts for the recap of all questions.

RESULTS AND DISCUSSION

The activity carried out by the Physics Learning Innovation Team had the theme "Training on Lesson Plans for Climate Change STEM Projects in Physics Learning for Sustainable Development." The training's target participants were physics teachers who were members of the Physics Teacher Conference (*MGMP)* in the Nganjuk District.

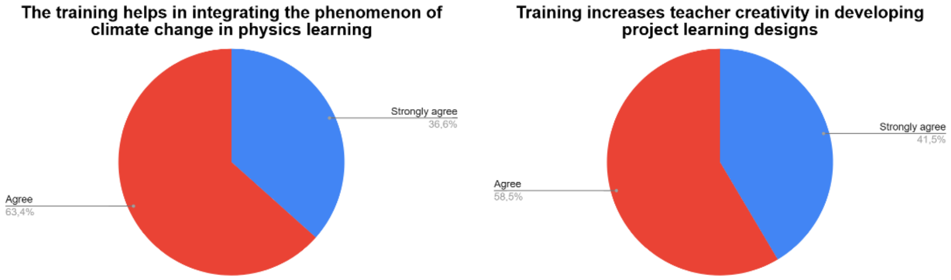
Figure 6 (a) shows the responses of the training participants regarding the Preparation of STEM Project Learning Plans in Climate Change Materials on the Implementation of ESD in Schools to the question, "Did participants gain knowledge about project-based physics learning?" Based on the distributed questionnaire, 48.8% of the training participants strongly agreed, while 51.2% agreed. Figure 6 (b) shows participants' responses in the Training on the Preparation of STEM Project Learning Plans in Climate Change Materials on the Implementation of ESD in Schools to the question, "Through this training, did I gain an overview of the implementation of project learning?" Based on the distributed questionnaire, 46.3% of the training participants strongly agreed, while 53.7% agreed.



(a) (b)

Figure 6 (a) Trainees' response to project-based physics learning and (b) Trainees' response to the implementation of project learning

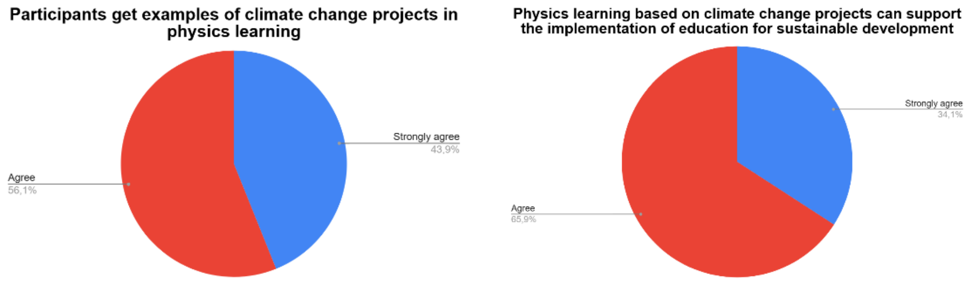
Figure 7 (a) shows the participants' responses in the Training on the Preparation of STEM Project Learning Plans in Climate Change Materials on the Implementation of ESD in Schools to the question, "Did the training help in integrating the climate change phenomenon into physics learning?" Based on the distributed questionnaire, 36.6% of the trainees strongly agreed, while 63.4% agreed. Figure 7 (b) shows the responses of the training participants regarding the Preparation of STEM Project Learning Plans in Climate Change Materials on the Implementation of ESD in Schools to the question, "Did the training increase teacher creativity in developing project learning designs?" Based on the distributed questionnaire, 41.5% of the training participants strongly agreed, while 58.5% agreed.



(a) (b)

Figure 7 (a) Trainees’ responses regarding the integration of climate change phenomena in physics learning and (b) Response of training participants related to increasing teacher creativity in developing project learning designs

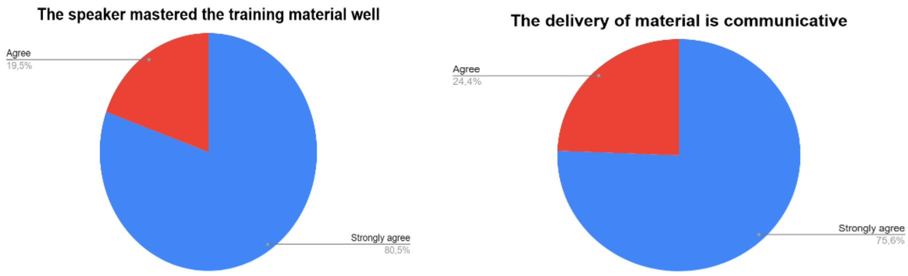
Figure 8 (a) shows the participants' responses in the Training on the Preparation of STEM Project Learning Plans in Climate Change Materials on the Implementation of ESD in Schools to the question, “Did participants receive examples of climate change projects in physics learning?” Based on the distributed questionnaire, 43.9% of the training participants strongly agreed, while 56.1% agreed. Figure 8 (b) shows the participant's responses in training on preparing STEM project lesson plans in climate change materials on the implementation of ESD in schools to the question, “Did physics learning based on climate change projects support the implementation of ESD?” Based on the distributed questionnaire, 34.1% of the trainees strongly agreed, while 65.9% agreed.



(a) (b)

Figure 8 (a) Trainees’ responses to examples of climate change projects in physics learning and (b) Trainees’ responses regarding physics learning based on climate change projects could support the implementation of ESD

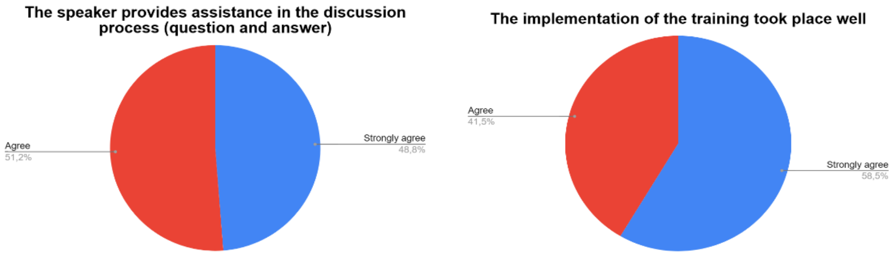
Figure 9 (a) shows the responses of the training participants regarding the Preparation of STEM Project Learning Plans in Climate Change Materials on the Implementation of ESD in Schools to the question, “Did the speaker master the training material well?” Based on the distributed questionnaire, 80.5% of the training participants strongly agreed, while 19.5% agreed. Figure 9 (b) shows the participants' responses to the training on preparing STEM project learning plans in climate change materials and implementing ESD in schools. The training addressed the question, “The delivery of material is communicative.” Based on the distributed questionnaire, 75.6% of the trainees strongly agree, and 24.4% agree.



(a) (b)

Figure 9 (a) Trainees’ responses related to the speaker mastering the training material well and (b) Trainees’ responses regarding the delivery of material were communicative

Figure 10 (a) shows the participants' responses in the Training on the Preparation of STEM Project Learning Plans in Climate Change Materials on the Implementation of ESD in Schools to ask, “Did the speaker assist in the discussion process (question and answer)?” Based on the distributed questionnaire, 48.8% of the trainees strongly agreed, while 51.2% agreed. Figure 10 (b) shows the participants' responses in the Training on the Preparation of STEM Project Learning Plans in Climate Change Materials on the Implementation of ESD in Schools to the question, “Implemented the training take place well?” Based on the distributed questionnaire, 58.5% of the trainees strongly agreed, while 41.5% agreed.



(a) (b)

Figure 10 (a) Response of trainees related to the speaker assisting in the discussion process (question and answer) and (b) Trainees’ responses regarding the implementation of the training were good

Figure 11 shows the responses of the training participants regarding the preparation of STEM Project Learning Plans in Climate Change Material on the Implementation of ESD in Schools to the question, “Did this training provide benefits related to physics learning planning?” Based on the distributed questionnaire, 63.4% of the training participants strongly agreed, while 36.6% agreed.

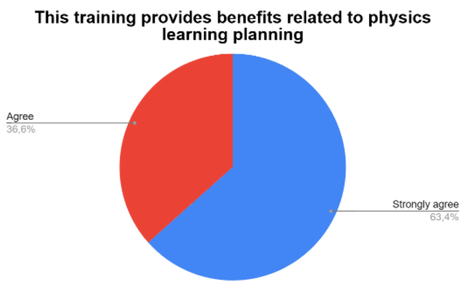


Figure 11 Trainees’ responses on the benefits of physics lesson design

Figure 12 shows the questionnaire results, which consist of several aspects: knowledge, skill, attitude, and effectiveness. Based on the diagram, Attitude had the highest average, represented by a red color. Effectiveness also had a reasonably high average, just below the Attitude results, represented by a blue color. Following that was Skill, represented by a gray color, and lastly, Knowledge, represented by a yellow color.

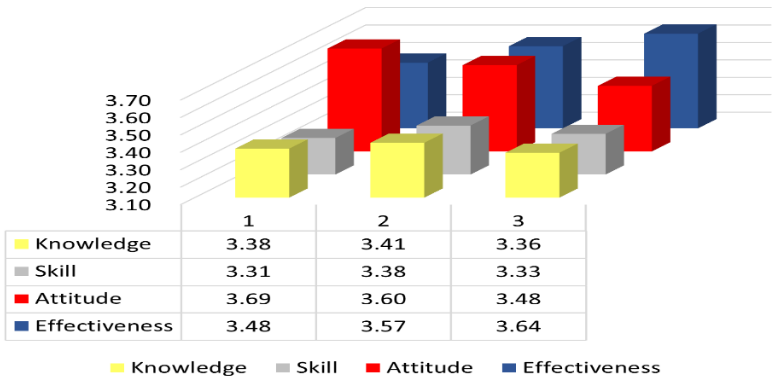


Figure 12 Recap of all questionnaire answers by trainees

Table 1 summarizes the participants' answers. Most of the trainees responded that the duration of the training was too short, but they felt that the training provided motivation and innovation as inspirational tools for physics learning.

Table 1 Recap of open-ended questionnaire answers by trainees

Question	**Answer**
What are the things that need to be improved in this training?	• The duration can be longer so that the discussion becomes more thorough. • Providing project examples is expected to be more detailed. • For instance, the STEM material is not explained in detail, and efforts are made to stay on time to maximize the event. • More time is needed for the delivery of material. • The delivery of the material is too fast. • Everything is good; hopefully, future training in Nganjuk can be even better. • Participants are from high schools and vocational schools, where science and social studies (*IPAS*) subjects are mixed. • Ice-breaking activities are needed. • The text on the tiny PPT is not legible from the back; this can be an evaluation point for future occasions. • Grouping participants based on RBK is suggested. • There should be practice sessions for the projects being worked on.
What was the most memorable part of the training for you?	• Presented real and simply, providing inspiration to be conveyed in learning. • The presenter delivered the material clearly, making it easy to understand. • Motivated the material presented by the speaker. • Allowed participants to meet *PPG* lecturers, previously only available online, and receive various learning kits. • The delivery of the material was integrated into everyday life. • The material was delivered engagingly. • The presentation of the material was good, allowing for an understanding of what was being delivered in a relaxed, non-tense environment. • Included an explanation of alternative energy learning media, such as the demonstration of a Stirling engine.

Question	Answer
	• The material provided was exceptional, showcasing interesting and innovative learning kits that motivate participants to explore further. • The speaker was patient, and the material supported the learning process. • The speaker was communicative and friendly. • Emphasized aspects of project-based learning. • There was tangible evidence of project creation.
In the future, what training should be provided to improve your professionalism?	• Deepening the alternative energy learning project within the independent curriculum. • Focusing on learning innovations, media, and new learning tools. • HOT (Higher Order Thinking) learning training. • Project-based training like this (STEAM) hones all students' abilities through meaningful learning. • Materials that can be applied in everyday life. • Training that helps teachers stay up to date with technology. • Developing literacy and numeracy assessments. • Training to create learning media that increases student interest. • The training provided needs to be guided more optimally. • A desire to create contextual learning media directly or to have training related to making contextual learning media based on theory. • Creating numeracy literacy learning media. • Practicing the creation of learning media and lesson plans. • Future training should focus on practical teaching methods for students that are simple yet complex.

The material was presented as an initial introduction or insight for the training participants, aiming to support the success of the assignments. Figure 13 documents the presentation of material to the training participants and the question-and-answer session.

(a) (b)

Figure 13 (a) Presentation of material given to training participants and (b) Discussion session related to the presentation of the material provided

After all stages of the training were completed, the participants were assigned to evaluate the training results in terms of whether there were temporary or permanent changes. Figure 14 shows an example of the participants' work on the assignments given.

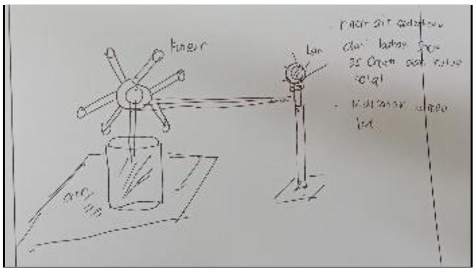


Figure 14 An example of the results of the training participant's assignment as a reflection

STEM education has been widely implemented to improve the quality of teaching and learning activities, such as enhancing student performance, particularly in science, technology, engineering, and mathematics (Ouyang, 2024). Future STEM education should integrate the principles of ecology, sustainable practices, and environmental responsibility. This involves implementing real ecological challenges into the curriculum to encourage students to develop solutions to climate change, pollution, and resource depletion. STEM education should empower students to become environmentally conscious citizens and professionals contributing to sustainable innovation (Hamad, 2024).

The integration and application of real-world problem solutions to support sustainable development through STEM education already existed in Indonesia, focusing on global issues covered in the Sustainable Development Goals (SDGs). UNESCO's SDGs made learning relevant and meaningful by guiding learners to make informed decisions and act responsibly in the context of their lives. Implementing the pilot project helped validate the materials and identify errors that needed correction (Nugroho, 2022).

Climate change, an urgent global issue with far-reaching consequences for the planet and future generations (Romero, 2024), was defined as long-term changes in temperature, precipitation, and weather patterns largely caused by human activities such as fossil fuel use and deforestation. It is a complex and multifaceted problem that requires a multidisciplinary approach and creative solutions (Lestari, 2024). Exposing learners to climate change gave them critical thinking skills, problem-solving abilities, and a sense of environmental responsibility. This choice was fully in line with the STEM education goals, which aim to integrate science, technology, engineering, and math to solve complex problems and stimulate creativity and innovation (Maspul, 2024).

Teaching materials improved students' problem-solving abilities and provided more information through these materials by stimulating students' curiosity and interest in the subject (Solihah, 2024). By integrating projects into learning, participants became more literate and motivated, making it easier to absorb the material because it was driven by context and included real examples.

Item Difficulty Level

The benefit of using Rasch analysis with Winstep was its ability to generate a map that presented the distribution of subject skills and item difficulty on a single scale. As illustrated by the Wright map, the range of item difficulties did not fully encompass the range of subject abilities. The available question difficulties did not adequately assess some highly skilled participants. The most challenging item, in this case, corresponded to S3, which represented the highest skill level at the third point. Question items A1 and A2 had low difficulty values, indicating that students consciously recognized that the mastery and delivery of the material by the speaker were very good. Furthermore, question item S3 had a high difficulty for participants to answer. This indicated that participants remained uncertain about the effectiveness of the project-based learning model applied to physics learning, especially regarding climate change material that could support sustainable development. This uncertainty occurred because the time allocated for training was very short, although the presenters delivered the material very well. In addition, participants also complained about the lack of examples of the application of project-based learning on climate change. Figure 15 show Item map / Wright map rash result.

```
        Person - MAP - Item
            <more>|<rare>
 78      XXXXX   +
 77         XX   +
 76              +
 75              +
 74              +
 73             T+
 72              +
 71              +
 70              +T
 69              +
 68              +
 67              +
 66              +
 65              +
 64              +
 63         XX   +
 62             S+   S3
 61              +
 60              +S  K3        S1
 59       XXXX   +
 58              +
 57              +   A3        S2
 56              +
 55              +   K1        K2
 54    XXXXXXX   +
 53              +
 52              +
 51              +
 50     XXXXXX  M+M
 49              +
 48              +
 47              +
 46          X   +
 45              +
 44              +   E2
 43              +
 42         XX   +   E1
 41              +
 40              +S  E3
 39             S+
 38              +
 37     XXXXXX   +   A2
 36              +
 35              +
 34              +
 33              +
 32              +   A1
 31         XX   +
 30       XXXX   +T
            <less>|<frequ>
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Figure 15 Item map/wright map

The results of Rasch analysis using Winstep showed that a high logit (measure) value signified a relatively high level of item difficulty. This aligned with the total score, where fewer correct answers corresponded to a higher measure value. Additionally, the item measure data was presented on a consistent scale. Item S3's measure value was 61.89, almost twice that of item A1, whose measure value was 32.20. Thus, item S3 had virtually twice the difficulty level of item A1. This calculation algorithm used the probability odds ratio and logit transformation, which showed the exact difficulty level in the same interval.

Based on the results from the item measure (Figure 16), the measure values indicated the level of difficulty of the questions. The highest score was for question S3 (Skill point 3), which showed a relatively high difficulty level, while the lowest was for question A1 (Attitude point 1).

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PT-MEASURE CORR.	PT-MEASURE EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
6	137	41	61.89	4.37	.79	-1.0	.62	-1.1	.69	.62	78.1	76.3	S3
3	138	41	60.03	4.25	.96	-.2	1.03	.2	.62	.61	75.0	74.1	K3
4	138	41	60.03	4.25	1.15	.8	1.23	.8	.56	.61	75.0	74.1	S1
5	140	41	56.58	4.09	.81	-1.2	.67	-1.3	.68	.61	75.0	70.6	S2
9	140	41	56.58	4.09	1.07	.5	1.11	.5	.58	.61	62.5	70.6	A3
1	141	41	54.94	4.03	.98	-.1	.91	-.3	.62	.61	65.6	69.1	K1
2	141	41	54.94	4.03	.87	-.8	.82	-.7	.65	.61	71.9	69.1	K2
11	148	41	43.79	4.09	.88	-.6	1.57	1.7	.60	.60	81.3	72.9	E2
10	149	41	42.10	4.15	1.02	.2	1.06	.3	.58	.59	78.1	73.7	E1
12	150	41	40.35	4.24	.91	-.4	.81	-.4	.62	.59	75.0	74.7	E3
8	152	41	36.57	4.49	1.14	.7	1.17	.5	.55	.59	75.0	76.6	A2
7	154	41	32.20	4.89	1.32	1.2	1.54	1.0	.49	.59	75.0	81.5	A1
MEAN	144.0	41.0	50.00	4.25	.99	-.1	1.04	.1			74.0	73.6	
S.D.	5.9	.0	9.87	.24	.15	.7	.29	.8			5.0	3.4	

Figure 16 Item measure

Item Compliance

Item fit was used to assess how well an item aligned with the model, indicating whether the question properly measured the intended construct. A lack of fit suggested that the item was not behaving as expected, which might have pointed to a misunderstanding by the subject when answering the question.

In Figure 17, the values for Outfit Mean Square (MNSQ), Outfit Z-standard (ZSTD), and Point Measure Correlation complied with the established guidelines. The Point Measure Correlation value showed how much the question was able to differentiate between subjects with high and low ability.

Outfit mean-square, outfit z-standard, and point measure correlation values were commonly used as standard criteria to evaluate an item's level of fit. If an item failed to meet these criteria, it indicated a lack of conformity with the model, suggesting that it was better to improve the instrument. The standard criteria for item suitability, according to Boone et al. (2014), are as follows:

- Accepted *Outfit Mean Square (MNSQ)* value : 0,5 < MNSQ < 1,5
- Accepted *Outfit Z-standard (ZSTD)* value : -2,0 < ZSTD < +2,0
- Accepted *Point Measure Correlation* value : 0,4 < *pt measure corr* <0,85

ENTRY NUMBER	TOTAL SCORE	TOTAL COUNT	MEASURE	MODEL S.E.	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD	PT-MEASURE CORR.	PT-MEASURE EXP.	EXACT MATCH OBS%	EXACT MATCH EXP%	Item
11	148	41	43.79	4.09	.88	-.6	1.57	1.7	A .60	.60	81.3	72.9	E2
7	154	41	32.20	4.89	1.32	1.2	1.54	1.0	B .49	.59	75.0	81.5	A1
4	138	41	60.03	4.25	1.15	.8	1.23	.8	C .56	.61	75.0	74.1	S1
8	152	41	36.57	4.49	1.14	.7	1.17	.5	D .55	.59	75.0	76.6	A2
9	140	41	56.58	4.09	1.07	.5	1.11	.5	E .58	.61	62.5	70.6	A3
10	149	41	42.10	4.15	1.02	.2	1.06	.3	F .58	.59	78.1	73.7	E1
3	138	41	60.03	4.25	.96	-.2	1.03	.2	f .62	.61	75.0	74.1	K3
1	141	41	54.94	4.03	.98	-.1	.91	-.3	e .62	.61	65.6	69.1	K1
12	150	41	40.35	4.24	.91	-.4	.81	-.4	d .62	.59	75.0	74.7	E3
2	141	41	54.94	4.03	.87	-.8	.82	-.7	c .65	.61	71.9	69.1	K2
5	140	41	56.58	4.09	.81	-1.2	.67	-1.3	b .68	.61	75.0	70.6	S2
6	137	41	61.89	4.37	.79	-1.0	.62	-1.1	a .69	.62	78.1	76.3	S3
MEAN	144.0	41.0	50.00	4.25	.99	-.1	1.04	.1			74.0	73.6	
S.D.	5.9	.0	9.87	.24	.15	.7	.29	.8			5.0	3.4	

Figure 17 Item fit

Furthermore, Figure 18 shows that the average ability values possessed by the subjects were distinguished well.

ENTRY NUMBER	DATA CODE	SCORE VALUE	DATA COUNT	%	AVERAGE ABILITY	S.E. MEAN	OUTF MNSQ	PTMEA CORR.	Item
11 A	3	3	16	39	34.92	4.89	2.1	-.60	E2
	4	4	25	61	61.54	3.25	.7	.60	
7 B	3	3	10	24	32.70	6.85	1.6	-.49	A1
	4	4	31	76	57.11	3.32	1.2	.49	
4 C	3	3	26	63	41.92	3.35	1.0	-.56	S1
	4	4	15	37	67.15	5.19	1.3	.56	
8 D	3	3	12	29	32.88	5.67	1.2	-.55	A2
	4	4	29	71	58.71	3.35	1.1	.55	
9 E	3	3	24	59	40.57	3.47	1.0	-.58	A3
	4	4	17	41	66.09	4.65	1.2	.58	
10 F	3	3	15	37	34.64	4.70	1.1	-.58	E1
	4	4	26	63	60.68	3.49	1.1	.58	
3 f	3	3	26	63	41.01	3.35	1.2	-.62	K3
	4	4	15	37	68.74	4.58	.9	.62	
1 e	3	3	23	56	39.37	3.53	.9	-.62	K1
	4	4	18	44	66.20	4.21	.9	.62	
12 d	3	3	14	34	32.48	4.59	.8	-.62	E3
	4	4	27	66	60.84	3.32	.9	.62	
2 c	3	3	23	56	38.81	3.40	.8	-.65	K2
	4	4	18	44	66.92	4.11	.8	.65	
5 b	3	3	24	59	38.92	3.31	.8	-.68	S2
	4	4	17	41	68.42	3.97	.6	.68	
6 a	3	3	27	66	40.49	3.07	.8	-.69	S3
	4	4	14	34	71.72	4.33	.6	.69	

Figure 18 Distractor frequency

Figure 19 shows that the mean measure was 51.15, indicating a positive value. This showed that the average ability of the subjects was higher than the level of difficulty of the test used. The person reliability value was 0.74, and the separation was 1.69.

	TOTAL SCORE	COUNT	MEASURE	MODEL ERROR	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	42.1	12.0	51.15	9.57				
S.D.	3.5	.0	21.53	4.81				
MAX.	48.0	12.0	90.20	18.52				
MIN.	36.0	12.0	8.89	6.42	.54	-2.0	.37	-1.9

REAL RMSE 10.94 TRUE SD 18.54 SEPARATION 1.69 Person RELIABILITY .74
MODEL RMSE 10.72 TRUE SD 18.67 SEPARATION 1.74 Person RELIABILITY .75
S.E. OF Person MEAN = 3.40

Figure 19 Summary statistics measure the person

These values indicated that the subjects provided fairly consistent answers, although their ability was not strong in range. By using the formula:

$$H = [(4 \times separation) + 1] / 3$$

To see a more detailed grouping of the subjects' abilities, it was found that there were three groups with different abilities.
From Figure 20, the person reliability value was 0.74 and the separation was 1.69

	TOTAL SCORE	COUNT	MEASURE	MODEL ERROR	INFIT MNSQ	INFIT ZSTD	OUTFIT MNSQ	OUTFIT ZSTD
MEAN	144.0	41.0	50.00	4.25	.99	-.1	1.04	.1
S.D.	5.9	.0	9.87	.24	.15	.7	.29	.8
MAX.	154.0	41.0	61.89	4.89	1.32	1.2	1.57	1.7
MIN.	137.0	41.0	32.20	4.03	.79	-1.2	.62	-1.3

REAL RMSE 4.40 TRUE SD 8.84 SEPARATION 2.01 Item RELIABILITY .80
MODEL RMSE 4.25 TRUE SD 8.91 SEPARATION 2.09 Item RELIABILITY .81
S.E. OF Item MEAN = 2.98

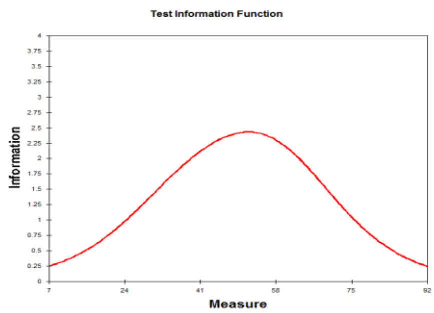
Figure 20 Summary statistics measure item

These values indicated that the item was not good to use and had difficulty ranging from easy to difficult. By using the formula:

$$H = [(4 \times separation) + 1] / 3$$

To see a more detailed grouping of the item difficulty level, 3 groups with different item difficulty levels were found. Furthermore, the Cronbach Alpha value was 0.85.

From Figure 21, the curve was shows that the test provided good information when given to subjects with moderate abilities. When given to subjects with low or high abilities, it only provided limited information.



Measurement Information Function
Figure 21 Function information test graph

Unidimensionality

The purpose of the undimensionality test was to assess whether the instrument was capable of measuring a single variable. This test was also referred to as the construct validation of the instrument. Factor analysis was used to identify the dimensions of the instrument and explore the relationships between different variables by analyzing the eigenvalues within the variance-covariance matrix.

This unidimensionality test produced an output in the form of an eigenvalue or raw data variance of 31.4%. These results indicated that the unidimensionality of the instrument, with a minimum value of 20%, was met. The unexplained variance values were 16.1, 10.9, 7.9, 6.9, and 6.4. This showed that the unexplained variance in several instruments was less than 10%, which meant that the uniformity in the instruments was categorized as good.

Since the validation data obtained from this research instrument clearly showed that it was of good quality, it represented that the research objectives had been achieved and supported the proposed hypothesis with consistent and relevant evidence. Thus, the results of this study can be considered to represent success in achieving the stated objectives, namely increasing teacher contributions in designing engaging STEM project-based physics learning to support sustainable development.

CONCLUSION

Project-based learning integrated with the STEM approach was used as a form of educational implementation to increase environmental awareness of the importance of climate change in supporting sustainable development. Providing examples of STEM projects during training increased teachers' contributions to designing engaging STEM project-based physics learning. The learning later utilized regional potential to support sustainable development.

The existence of aspects of science, technology, engineering, and mathematics helped students explore more knowledge, which could be retained in memory for the long term due to the multiple senses engaged in completing project assignments.

CONFLICTS OF INTEREST

The authors declare no known financial conflicts of interest or personal relationships that could have influenced the work reported in this manuscript.

AUTHOR CONTRIBUTIONS STATEMENT

Conceptualization, NAL and EH; methodology, BJ; formal analysis, NAL and DD; writing—preparation of the original draft, NAL and BKP; and all authors discussed the results and contributed to the final manuscript.

ACKNOWLEDGMENTS

The authors would sincerely like to thank the Faculty of Mathematics and Natural Sciences (FMIPA), Universitas Negeri Surabaya (UNESA), for research funding under the PKM FMIPA 2024 grant scheme.

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