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Learning Innovation: PBL-STEM 4H Ecobrick material Teaching for 7th Graders to Enhance Ecoliteracy

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Abstract. Teaching materials that accommodate innovative learning to improve environmental literacy are currently essential. Development research has been conducted to develop and examine the effectiveness of ecobrick theme teaching materials in improving student ecoliteracy. The teaching materials are packaged with the PBL-STEM 4H model (project based learning- science, technology, engineering, and mathematics - head, heart, hand, and harmony). The research employs research and development method and ADDIE design (analysis, design, development, implementation, and evaluation). This research uses interview guidelines, observation questionnaire sheets, and environmental literacy instruments as research instruments. In the development stage, this research employs several science teachers in the Sukabumi Regency, as determined by purposive sampling. In the implementation stage, 7th-grade students of one secondary school in West Java were tested to evaluate the effectiveness of the teaching materials in improving eco-literacy. Teaching materials were developed using PBL-STEM learning steps characterized by 4H values. The teaching materials' validation results show high validity with a feasibility score of 87.2, including a very valid category. The CVI (content validity index) and CVR (content validity ratio) indexes of 0.995 and 0.990 are included in the valid category. Teacher response to teaching materials reaches 90.05, including the outstanding category. The implementation results show that using the developed teaching materials during learning can improve student eco-literacy.
Keywords: Teaching materials, PjBL-STEM 4H, ecobricks, ecoliteracy, environmental pollution

Introduction

Education is one strategic way to achieve the sustainable development goals (SDGs) (Vilmala et al., 2022). SDGs are universally agreed goals to end poverty, protect the planet, reduce inequality, and protect environmental quality, which is on the agenda for the next fifteen years until 2030 (Umam et al., 2023). Within the SDGs, the education sector is covered in goal 4: quality of education (Chankseliani et al., 2021). The implementation of

Goal 4 plays an essential role in achieving other SDGs goals. The educational process can become a space to increase student awareness about environmental issues (Mawardin et al., 2015). Environmental education must be implemented to realize ecological understanding and awareness, or we can call it eco-literacy (Pitman et al., 2018). In addition, eco-literacy-based education is important for achieving SDGs (Sucia et al., 2018). Sufficient eco-literacy in the education sector would, in turn, assist the attainment of SDGs (Russo, 2020). Therefore, eco-literacy must be introduced since childhood or primary education (Rida et al., 2019; Hammarsten et al., 2019).

Based on observations, students' eco-literacy is still low and thus becomes a problem that must be addressed through the learning process. A survey of junior high school students in Sukabumi Regency revealed that the level of eco-literacy in the cognitive domain was good. However, in the affective and psychomotor domains, it was still low. From the survey results, 78 percent of students still waste clean water, while 0.06 percent are unaware of turning off the lights before leaving the classroom. Furthermore, 75 percent of students still buy bottled water rather than bring a reusable water bottle. The survey also revealed only 18 percent of students bring food from home. The rest prefer to buy food packaged in plastic or styrofoam. In addition, only 2.9% of students participated in waste-sorting activities. The low survey results align with other research results (Kadarisman, 2023), which show that students' eco-literacy skills are still low. Eco-literacy includes three core competencies: Head (knowledge), Heart (attitude), and Hand (skills) (Sya'diah, 2021). As the 3H (Head, Heart, and Hand) competencies have been reached, the last principle, Harmony, will also be reached (Agung, 2019). Based on that competency basis, in this study, the eco-literacy study would apply the 4H principle: Head, Heart, Hand, and Harmony.

The availability of relevant teaching materials supports the success of the learning process. Suitable teaching materials reflect the efforts to meet various needs for achieving learning objectives, are innovative and responsive to contemporary learning needs, and, at the same time, attract student interest (Kaniyah et al., 2022). In relation to eco-literacy-based learning, teaching materials should also accommodate the basic principles of society. Fundamental principles or values that strongly support conservation are 4H-based learning. Suitable teaching materials are those that meet high academic standards. Pedagogic standards of teaching material can be met if they accommodate innovative learning syntax. One of the learning models whose syntax can be adopted in developing teaching materials is project-based learning (PBL), which is oriented toward producing creative and innovative products through a science, technology, engineering, and mathematics (STEM) approach (PBL-STEM). Research shows that the PBL-STEM model improves science literacy and students' creative thinking skills (Srigati, 2019; Ratnasari, 2023; Susilawati, 2020). The previous research further states that STEM projects have increased creativity in formulating hypotheses, conducting experiments, drawing conclusions, and teaching evaluation (Sternberg et al., 2020). In addition, PBL-STEM aims to provide opportunities for students through projects to create products that can solve real-life problems (Ardianto et al., 2018).

STEM education has grown worldwide in response to the development of the 21st century and Industry 4.0. This education system has significantly improved students' understanding of ideas, literacy, and creativity (Rubini et al., 2023). Education for Creativity and Sustainability Development are two global agendas in 21st-century learning. Creative play and learning in the natural environment are used to develop creative eco-literacy in elementary school students (Nugroho et al., 2021). Increasing eco-literacy can be realized through various factors, including using multiple learning resources, such as applying project-based learning with eco-brick products utilizing plastic waste (Maulidah et al., 2021). By creating eco-brick projects, students and teachers succeeded in building a school facility, a literacy park whose entire skeleton came from recycled plastic waste

(Suhendri, 2022). Teaching materials must contain eco-literacy components to increase students' awareness to protect and preserve the environment (Rahmawati, 2019). After searching previous research using the keywords teaching materials, PjBL-STEM, eco-bricks, and 4H principles, this research found no prior research on the subject. Thus, a research gap exists for developing teaching and learning materials for PjBL-STEM 4H with eco-brick products related to increasing eco-literacy. The results of the bibliometric analysis of the Google Scholar database using Publish or Perish software and mapping with the help of the VOSviewer program show the research gap in this topic. Bibliometric results categorize prospective trends or research orientation based on author, title, and plus keywords. Author, title, and plus keywords are all used in this method (Chen et al., 2016).

One of the subjects related to eco-literacy is environmental pollution. Environmental pollution material can be integrated into the learning process by applying the themes. One of the currently exciting themes is eco-bricks. Eco-bricks can become a creative tool for handling plastic waste (Putri et al., 2019). Eco-bricks can be a tool for developing student creativity (Leria, 2020). Eco-bricking is a creative concept where PET (polyethylene terephthalate) bottles are densely packed with clean, dry scrap plastic, manually built to a specific density to absorb the plastic, and create a reusable product (ecobrick.org). The eco-brick context is closely related to the material on environmental pollution in the independent curriculum in class VII/phase D.

Based on the above background description, the problem of the low level of eco-literacy is proposed to be solved by providing teaching materials. The suggested teaching materials are characterized by PBL-STEM syntax by accommodating the primary value of 4H as a hallmark of efforts to increase students' environmental awareness with ecobrick materials or themes. The research question is as follows: *"What are the characteristics of PBL-STEM 4H ecobrick teaching materials that can improve student eco-literacy on environmental pollution material?"*. The results of the bibliometric analysis of the Google Scholar database on Publish or Perish software, mapped using the VOSviewer program, show the research gap in the topic. Bibliometric results categorize prospective trends or research orientation based on author, title, and plus keywords. Author, title, and plus keywords are all used in this method (Chen et al., 2016). Adopting the STEM-based problem-based learning (PBL) model in primary education enhances knowledge acquisition significantly, character development, and skill improvement. This approach enables students to identify environmental issues, generate solutions, design interventions, create products addressing them, and evaluate their effectiveness. Environmentally focused learning has proven effective in fostering positive student attitudes and knowledge. Moreover, implementing PBL in schools cultivates a supportive learning environment, encouraging students to engage in environmental conservation efforts actively (Wahdaniyah et al., 2023; Widowati et al., 2021).

Furthermore, the purpose of this paper is to develop and assess the effectiveness of teaching materials based on the PBL-STEM 4H model (Project-Based Learning with Science, Technology, Engineering, Mathematics - Head, Heart, Hand, and Harmony) using eco-brick themes to improve students' eco-literacy. The research aims to address the low levels of eco-literacy among students, particularly in the affective and psychomotor domains, and to create innovative educational materials that foster environmental awareness and sustainability. Specifically, it seeks to determine the characteristics of these teaching materials and their impact on students' understanding of environmental pollution.

Methods

The study was conducted in the Sukabumi Regency, divided into eight subdistricts. One public junior high school is chosen to represent each subdistrict. The eight subdistricts were Sukaraja, Cisaat, Cibadak, Cicurug, Cikembar, Palabuhan Ratu, Sagaranten, Surade. The research population is the science teachers in the Sukabumi Regency. This research uses purposive sampling as the sampling technique and chooses science teachers who are still actively teaching in 2024 from each subzone in the Sukabumi Regency. The total sample size is 13 people. In addition to the teachers, this study involves experts to obtain data on the validity and feasibility of the developed teaching materials.

Table 1. Sample Schools for Each Subdistrict in the Sukabumi Regency.

No	Subdistrict	School Name
1	Sukaraja	SMPN 1 Gegerbitung
2	Cisaat	SMPN 1 Cisaat
3	Cibadak	SMPN 3 Cibadak
4	Cicurug	SMPN 2 Cicurug
5	Cikembar	SMPN 2 Cikembar
6	Palabuhanratu	SMPN 4 Cisolok Satu Atap
7	Sagaranten	SMPN 2 Curug Kembar
8	Surade	SMPN 3 Cimanggu Satu Atap

The research method used in the development of teaching materials is research and development (R & D) with ADDIE (analysis, design, development, implementation, and evaluation) design (Rafles, 2023; Rai et al., 2021; Miskiyah & Buchori, 2023). The stages of developing teaching materials based on the ADDIE stages are presented in the flowchart in the Figure 1.

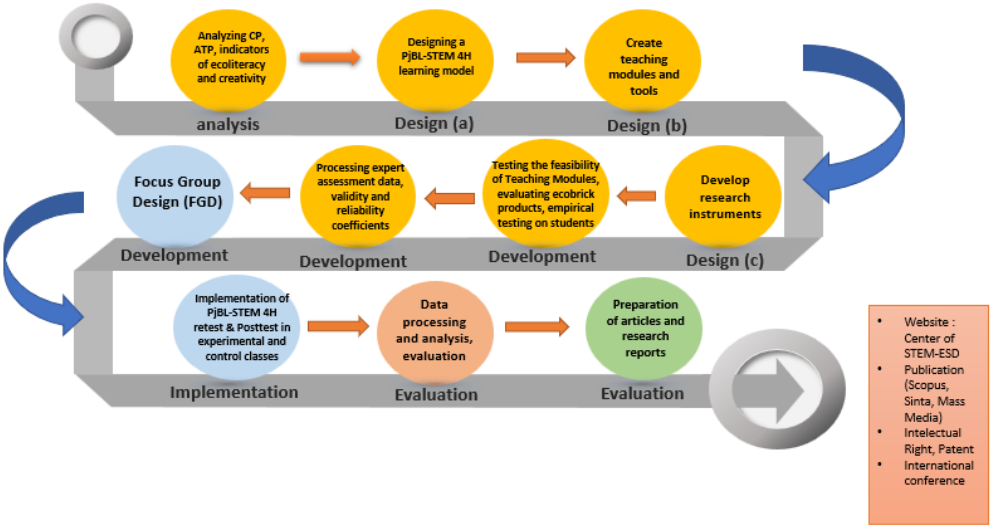


Figure 1. Flowchart of ADDIE Model Teaching Materials Development Research

This researcher directly collects primary data through (1) observation of the school under study, (2) questionnaires to science teachers, (3) validation and feasibility questionnaires and response questionnaires. The teaching material instrument has been validated and tested for reliability. Observation and questionnaire data were analyzed

descriptively. Questionnaire data was analyzed by calculating the percentage of answers with the following formula:

$$(\%)\ \text{Validity} = (\frac{\text{the score obtained}}{\text{maximum score}})\ \text{x}\ 100\%$$

The results of the value calculation are interpreted according to Table 2.

Table 2. Percentage Criteria

No	Interval	Validity Category	Response Categories
1	0 ≤ x ≤ 20	Very invalid	Very bad
2	21 ≤ x ≤ 40	Invalid	Not good
3	41 ≤ x ≤ 60	Quite valid	Pretty good
4	61 ≤ x ≤ 80	Valid	good
5	81 ≤ x ≤ 100	Very valid	Very good

(Source: Mutiara, et al., 2023)

Data from the validation results were calculated using the content validity ratio (CVR) and content validity index (CVI). CVR to measure the justification among raters for a particular item (Lawshe, 1975) with the following formula:

$$CVR = \frac{n_e - (N/2)}{N/_2} \qquad (2)$$

Description:
n_e: Number of respondents who stated: "Appropriate".
N: Total respondents

The CVR value ranges between -1 and 1; if half of all respondents stated, "Not Appropriate," then the CVR value = 0, while it = 1 when all respondents stated "Appropriate." The CVR value obtained from the calculation is accepted if it exceeds the minimum CVR value. The standard reference for item validity is shown in Table 3.

Table 3. Minimum Value CVR One-Tailed Test, p = 0.05

Number of Respondents	Minimum CVR Value
5	0.99
6	0.99
7	0.99
8	0.85
9	0.78
10	0.62
15	0.49
20	0.42

The CVI value determines whether the overall test is acceptable or not using the formula:

$$\text{CVI} = \frac{\Sigma\text{CVR}}{\text{number of sub-questions received}} \qquad (3)$$

The following validation stage is validation by science teachers. Validation was conducted with expert judgment and by 20 science teachers. The results of specialist judgment were then processed with CVR and CVI to determine the validity value. The average CVR result

is 0.990 and the average CVI is 0.995. According to Ayre & Scall (2014), the conclusion of the practitioner validation results using the CVI and CVR methods shows that the CVR and CVI values are in the Valid category.

Results and Discussion

Based on the research objectives, using the ADDIE model, PjBL-STEM 4H Ecobrick teaching materials have been developed and tested for validity and feasibility. The results of each stage of the activity according to the ADDIE model are as follows.

Needs Analysis Stage

The initial stage in the ADDIE development model is analysis. Needs analysis is part of module design (Farihah et al., 2021). The analysis includes analyzing learning, teaching material devices, and the ability of teachers to implement in schools (Lerian et Al., 2022). The analysis is carried out to determine the difference between expectations in learning and facts in the field (Asmar & Suryadarma, 2021). The analysis was conducted through observation to explore the information needed to develop teaching materials according to the needs and readiness of schools. The following information was obtained from the observation results.

The preliminary analysis showed that students' ecoliteracy is still low. The survey results of junior high school students in Sukabumi Regency showed that the level of eco-literacy in the cognitive domain was good. However, in the affective and psychomotor domains, it was still low. From the survey results, 78 percent of students still waste clean water, while 0.06 percent are unaware of turning off the classroom lights. Furthermore, 75 percent of students still choose to buy bottled water rather than bring a Tumblr. Only 18 percent of students bring supplies from home; the rest prefer to buy food packaged in plastic or styrofoam. In addition, only 2.9% of students participated in waste-sorting activities. The low level of students' eco-literacy is intricately linked to teachers' capabilities in effectively imparting literacy skills to their students. This relationship underscores the need for educators to adopt diverse and innovative teaching approaches and models that can address this gap in eco-literacy. One such contemporary learning model that has shown promise is Project-Based Learning integrated with STEM (PBL-STEM). However, a significant challenge arises because many educators do not comprehensively understand PBL-STEM-based learning methodologies.

Schools play a crucial role in this context, as they must facilitate a shift in community mindsets regarding education levels and environmental preservation. This undertaking is particularly daunting, given that a substantial portion of the community lacks a foundational background in environmental education, as highlighted by Iasha (2018) and Juniarso et al. (2020). The development of environmental literacy is essential for fostering a society that values ecological awareness and recognizes the vital importance of environmental conservation for the sustainability of human life. This perspective is further supported by McBride et al. (2013), who emphasize that cultivating an environmentally literate population is fundamental to achieving ecological and sustainability goals. Consequently, enhancing teachers' understanding and application of innovative teaching strategies like PBL-STEM is critical to bridging the gap in students' eco-literacy and ensuring a more environmentally conscious future. The initial study results show that 79% of teachers still struggle to understand the concept and methodology of PBL-STEM. 7% of respondents answered very difficult, and 14% answered easy. Sources of teaching materials used by respondents for PBL-STEM learning: 46% from the Internet, 23% from the Merdeka Teaching Portal (PMM), 15% design their own, 8% from MGMP IPA, and 8% from other sources. Respondents as many as 73% answered that it was challenging to design PBL-STEM learning that was interesting and meaningful to students,

and 8% responded that it was complicated. Only 15% answered that it was easy. As many as 79% of respondents answered that it is essential to develop PBL-STEM teaching materials, and the remaining 21% responded that it is necessary to develop teaching materials that make it easier for teachers to implement PBL-STEM.

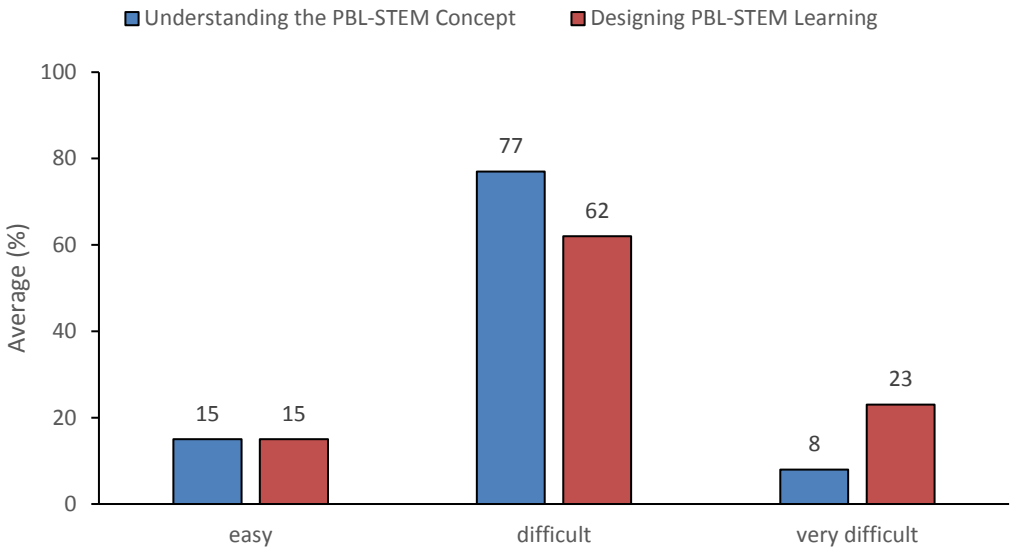


Figure 2. Teachers' Ability to Implement PBL-STEM

The chart shows that teachers face significant challenges in understanding and designing PBL-STEM (Project-Based Learning integrated with STEM). In contrast, 77% of teachers struggle to grasp the PBL-STEM concept; 62% struggle with designing lessons around it even more. Only a small fraction finds these tasks easy. This result highlights a gap between theoretical understanding and practical application, indicating the need for more training, resources, and support to help teachers effectively implement PBL-STEM in their classrooms. The data underscores the complexity of applying this approach and the urgency for professional development in this area.

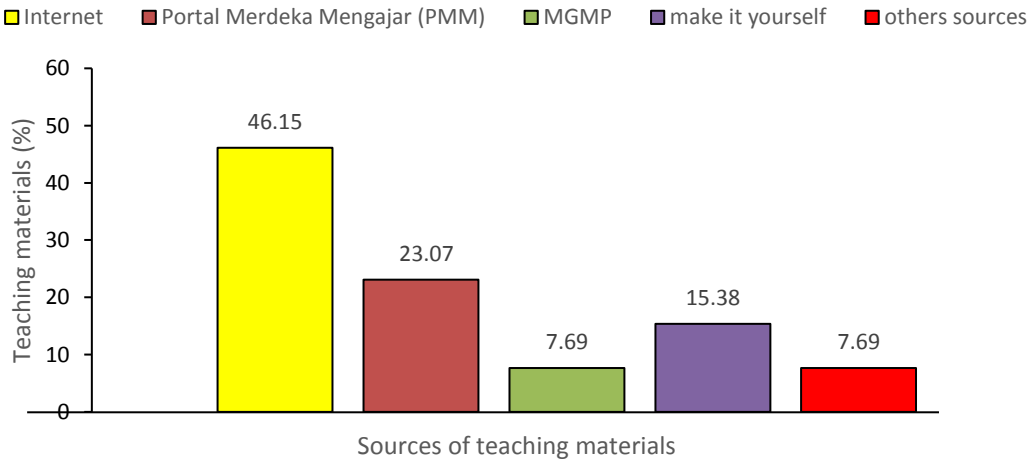


Figure 3. Sources of Teaching Materials Used by Teachers

The chart displays teachers' various sources of teaching materials, highlighting a clear preference for internet-based resources. 46.15% of teachers rely on the Internet for

their teaching materials, making it the dominant source. This result suggests that many educators find online resources more accessible, up-to-date, or comprehensive than other available options. Following this, 23.07% of teachers turn to the "portal merdeka mengajar," a platform designed to support the implementation of Indonesia's "Merdeka Belajar" (Freedom to Learn) policy. This relatively high percentage shows that the portal is gaining traction among educators as a key resource. Other methods include teachers creating their materials, with 15.38% opting for this approach, indicating a preference for customization when pre-existing resources may not fully meet their needs. Meanwhile, MGMP (Teacher Working Group) and other sources account for 7.69% each, signifying less reliance on these more traditional or collaborative methods. This distribution suggests that while the Internet is the go-to resource, teachers value professional networks and self-generated materials for specific teaching needs.

Furthermore, based on the responses from teachers regarding the need for developing teaching materials, 77% of teachers see it as 'necessary', while 23% view it as a 'need'. The most significant proportion of respondents, 77%, indicated that developing teaching materials is crucial. This result suggests that more than three-quarters of the teachers firmly believe that creating new or improved teaching materials is essential for effective teaching. This perception likely stems from the understanding that high-quality teaching materials contribute to better learning outcomes. Teachers in this group likely feel that the current teaching resources may be inadequate to meet the evolving demands of modern education and the diverse needs of students. Their strong consensus signals an urgent call for reform in how educational content is structured and delivered. It reflects a deep awareness among teachers about the shifting educational landscape and the necessity of aligning teaching resources with contemporary pedagogical practices.

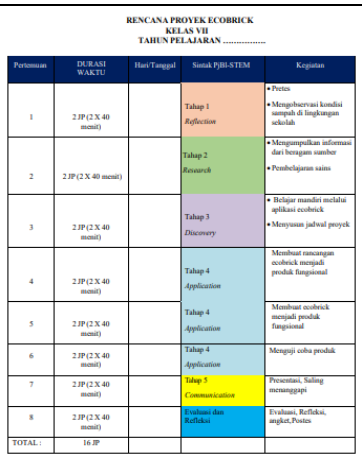
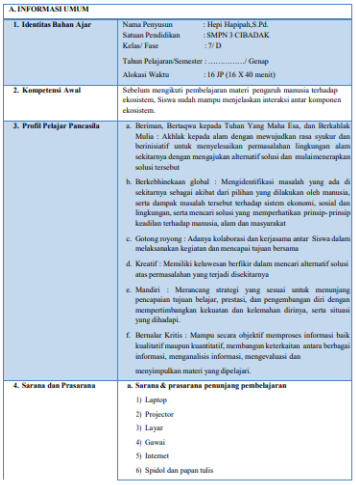
In contrast, the 'Need' category, representing 23% of respondents, takes a slightly different view. While this group acknowledges the importance of developing teaching materials, their perception reflects a lower sense of urgency than the majority. These teachers may recognize that new or improved resources would be beneficial, but they might believe that the existing materials are still somewhat effective in meeting their current needs. This group may prioritise other educational issues over the development of teaching materials or feel that the present resources are sufficient for their specific teaching contexts. In this sense, while they agree on the need for development, they do not view it as an immediate concern. Based on the need analysis, the solution to minimize teacher difficulties is to develop the teaching materials in question.

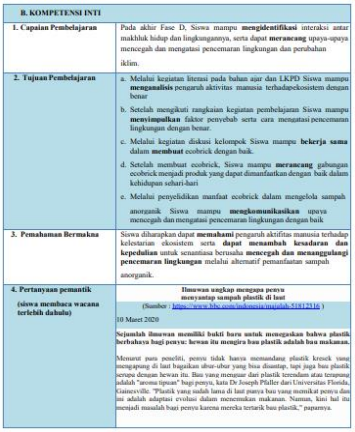
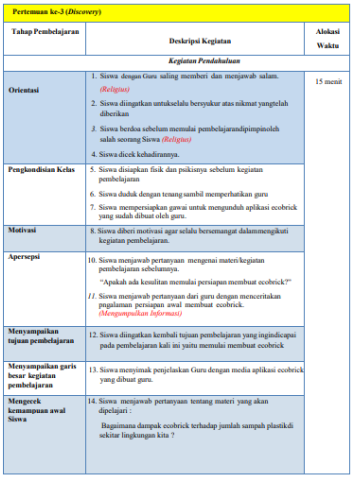
Planning Stage

The design stage is the second ADDIE research and development model stage. At this stage, flowcharts and storyboards are made as a basis for and description of the form, content, and appearance of teaching material development. At the design stage, the project plans, learning materials, activity stages, STEM content, products, learning support applications, and assessment instruments are harmonized (Bates, 2019). At this stage, reference collection is carried out, and a map of teaching material needs is prepared and designed for teaching materials.

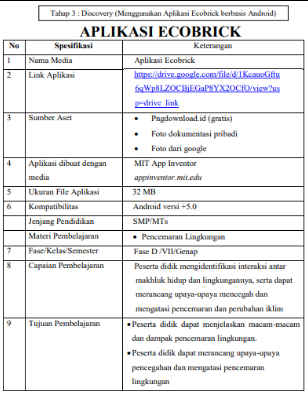
The initial design of the PjBL-STEM 4H Ecobrick Environmental Pollution teaching materials can be seen in Table 4.

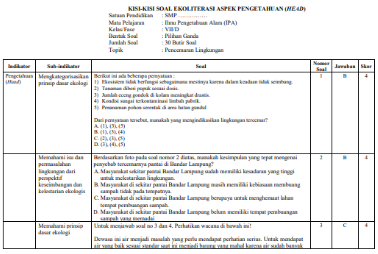
Table 4. Initial design display of teaching materials

Teaching Material Components	Display	Description
Cover		It includes title, education level, phase and grade, subject, material title, author's name, and reference curriculum.
Project Plans	 Pertemuan / DURASI WAKTU / Hari/Tanggal / Sintak PjBl-STEM / Kegiatan 1 / 2 JP (2 X 40 menit) / Tahap 1 Reflection / • Pretes • Mengobservasi kondisi sampah di lingkungan sekolah 2 / 2 JP (2 X 40 menit) / Tahap 2 Research / • Mengumpulkan informasi dari beragam sumber • Pembelajaran sains 3 / 2 JP (2 X 40 menit) / Tahap 3 Discovery / • Belajar mandiri melalui aplikasi ecobrick • Menyusun jadwal proyek 4 / 2 JP (2 X 40 menit) / Tahap 4 Application / Membuat rancangan ecobrick menjadi produk fungsional 5 / 2 JP (2 X 40 menit) / Tahap 4 Application / Membuat ecobrick menjadi produk fungsional 6 / 2 JP (2 X 40 menit) / Tahap 4 Application / Menguji coba produk 7 / 2 JP (2 X 40 menit) / Tahap 5 Communication / Presentasi, Saling menanggapi 8 / 2 JP (2 X 40 menit) / Evaluasi dan Refleksi / Evaluasi, Refleksi, angket, Postes TOTAL : 16 JP	It contains the project schedule from start to finish.
General Information		It contains the identity of teaching materials, initial competencies, Pancasila Learner Profile, facilities and infrastructure, target students, learning models and methods, PjBL and STEM linkages, and references.

Teaching Material Components	Display	Description
Special Information		It contains learning outcomes, objectives, meaningful understanding, triggering questions, and learning preparation.
Learning Activities		It contains stages of learning activities according to the syntax of the learning model and time allocation.
Attachment		It includes LKPD, PPT, assessment instruments, principal approval sheet, and bibliography.

<table>
<tr><th>Teaching Material Components</th><th>Display</th><th>Description</th></tr>
<tr><td>Supporting Materials

(Android-based eco-brick app)</td><td> 
Tahap 3 : Discovery (Menggunakan Aplikasi Ecobrick berbasis Android)
APLIKASI ECOBRICK
<table>
<tr><th>No</th><th>Spesifikasi</th><th>Keterangan</th></tr>
<tr><td>1</td><td>Nama Media</td><td>Aplikasi Ecobrick</td></tr>
<tr><td>2</td><td>Link Aplikasi</td><td>https://drive.google.com/file/d/1KcauoGftu6qWp8LZOCBjEGaP8YX2OCfO/view?usp=drive_link</td></tr>
<tr><td>3</td><td>Sumber Aset</td><td>• Pngdownload.id (gratis)
• Foto dokumentasi pribadi
• Foto dari google</td></tr>
<tr><td>4</td><td>Aplikasi dibuat dengan media</td><td>MIT App Inventor
appinventor.mit.edu</td></tr>
<tr><td>5</td><td>Ukuran File Aplikasi</td><td>32 MB</td></tr>
<tr><td>6</td><td>Kompatibilitas</td><td>Android versi +5.0</td></tr>
<tr><td></td><td>Jenjang Pendidikan</td><td>SMP/MTs</td></tr>
<tr><td></td><td>Materi Pembelajaran</td><td>• Pencemaran Lingkungan</td></tr>
<tr><td>7</td><td>Fase/Kelas/Semester</td><td>Fase D /VII/Genap</td></tr>
<tr><td>8</td><td>Capaian Pembelajaran</td><td>Peserta didik mengidentifikasi interaksi antar makhluk hidup dan lingkungannya, serta dapat merancang upaya-upaya mencegah dan mengatasi pencemaran dan perubahan iklim</td></tr>
<tr><td>9</td><td>Tujuan Pembelajaran</td><td>• Peserta didik dapat menjelaskan macam-macam dan dampak pencemaran lingkungan.
• Peserta didik dapat merancang upaya-upaya pencegahan dan mengatasi pencemaran lingkungan</td></tr>
</table></td><td>It includes the identity, concept of environmental pollution, eco-brick linkage to PjBL-STEM, and displays student work.</td></tr>
<tr><td>Supporting Materials

(Ecoliteracy Supplement)</td><td> 
KISI-KISI SOAL EKOLITERASI ASPEK PENGETAHUAN (HEAD)
Satuan Pendidikan : SMP ....
Mata Pelajaran : Ilmu Pengetahuan Alam (IPA)
Kelas/Fase : VII/D
Bentuk Soal : Pilihan Ganda
Jumlah Soal : 30 Butir Soal
Topik : Pencemaran Lingkungan
<table>
<tr><th>Indikator</th><th>Sub-indikator</th><th>Soal</th><th>Nomor Soal</th><th>Jawaban</th><th>Skor</th></tr>
<tr><td>Pengetahuan (Head)</td><td>Mengkategorisasikan prinsip dasar ekologi</td><td>Berikut ini ada beberapa pernyataan :
1) Ekosistem tidak berfungsi sebagaimana mestinya karena dalam keadaan tidak seimbang.
2) Tanaman diberi pupuk sesuai dosis.
3) Jumlah eceng gondok di kolam meningkat drastis.
4) Kondisi sungai terkontaminasi limbah pabrik.
5) Penanaman pohon serentak di area hutan gundul

Dari pernyataan tersebut, manakah yang mengindikasikan lingkungan tercemar?
A. (1), (3), (5)
B. (1), (3), (4)
C. (2), (3), (5)
D. (3), (4), (5)</td><td>1</td><td>B</td><td>4</td></tr>
<tr><td></td><td>Memahami isu dan permasalahan lingkungan dari perspektif keseimbangan dan kelestarian ekologis</td><td>Berdasarkan foto pada soal nomor 2 diatas, manakah kesimpulan yang tepat mengenai penyebab tercemarnya pantai di Bandar Lampung?
A. Masyarakat sekitar pantai Bandar Lampung sudah memiliki kesadaran yang tinggi untuk melestarikan lingkungan.
B. Masyarakat di sekitar pantai Bandar Lampung masih memiliki kebiasaan membuang sampah tidak pada tempatnya.
C. Masyarakat di sekitar pantai Bandar Lampung berupaya untuk menghemat lahan tempat pembuangan sampah.
D. Masyarakat di sekitar pantai Bandar Lampung belum memiliki tempat pembuangan sampah yang memadai</td><td>2</td><td>B</td><td>4</td></tr>
<tr><td></td><td>Memahami prinsip dasar ekologi</td><td>Untuk menjawab soal no 3 dan 4. Perhatikan wacana di bawah ini!

Dewasa ini air menjadi masalah yang perlu mendapat perhatian serius. Untuk mendapat air yang baik sesuai standar saat ini menjadi barang yang mahal karena air sudah banyak</td><td>3</td><td>C</td><td>4</td></tr>
</table></td><td>Load the Head, Heart, Hand, Harmony (4H) domain Ecoliteration instrument.</td></tr>
</table>

Development Stage

The third stage is the development stage. At this stage, the interactive multimedia design that has been made is realized. The initial design of teaching materials was validated and tested for feasibility by learning experts, namely education expert lecturers. The results of the validation process and feasibility test are a reference for revising the initial design of teaching materials. The validation process is carried out by submitting a draft of the initial design of teaching materials to the validator, accompanied by a validation questionnaire. The results of the recapitulation of the validator's answers to the validation questionnaire can be seen in Table 5.

Table 5. Recapitulation of Validation Questionnaire Answers

No	Aspects Validated	Question Number	Validation of (%)
1	Teaching Material Display	1-3	87
2	General Information and Special Information	4-6	85
3	Project Linkage with PjBL-STEM model	7-9	89
4	Learning Activity Design	10	87
5	Supporting Materials	11-15	88
	Total Percentage		87.2

Based on Table 5, the highest validation percentage is in project linkage with the PjBL-STEM model, while the lowest rate is in general and specific information. In addition to

quantitative data, researchers also explored criticism and suggestions for improving the teaching materials developed. The following are suggestions submitted by validators.

Table 6. Validator Suggestions for Teaching Materials

No	Validator suggestions
1	The triggering question is preceded by a discourse related to a real-world problem
2	Ecobrick applications reinforced concept/theory
3	In eco-brick applications, STEM steps must be reinforced
4	Students are given the freedom to create ecobrick designs that may be different.
5	Some sentences in the assessment instrument were redacted
6	The concept of environmental pollution is made in the form of a narrative

In addition to validation data, the teacher's response as a user is known from the results of the response questionnaire, which can be seen in Figure 4.

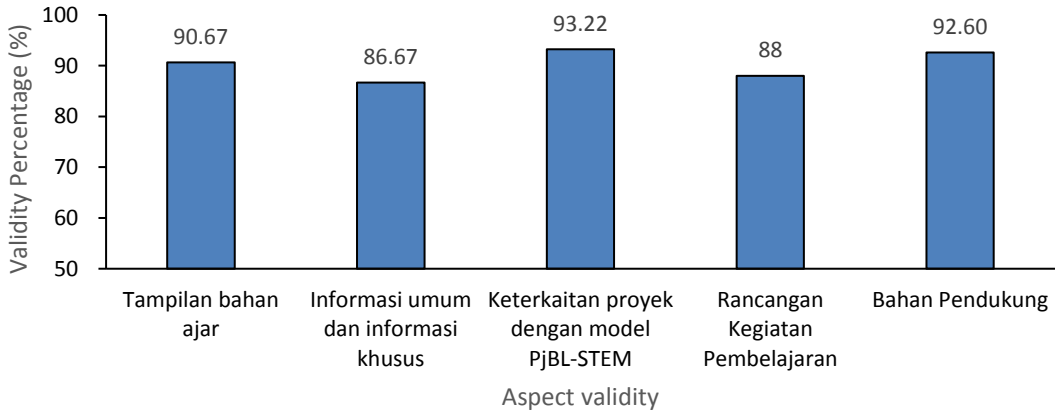


Figure 4. Data from The Results of The Teacher Response Questionnaire on Each Aspect

The CVI and CVR index values of 0.995 and 0.990 indicate that, in general, the teaching materials that have been developed are suitable for use because they have met the validity in the very high category. This data is reinforced by the % validation based on the validation questionnaire by teachers who are also in the outstanding category, with an index of 87.5%. The overall percentage of teacher responses to the questionnaire is 90.05%, and based on Table 2, it is also in the outstanding category. These results show that teaching materials are feasible, and teachers can use them well to implement them in learning. Figure 5 shows that the highest percentage of teacher responses to teaching materials is in project linkage with the PjBL-STEM model. These results indicate that the teaching materials are following the needs of educators. This aspect is essential because it can affect students' motivation to participate in learning actively.

Implementation Stage

At this stage, the teaching materials that have been prepared and tested for feasibility are then used in real learning in the classroom. Students in one class, totalling 32 people, were divided into four groups. Before learning, students are given an eco-literacy post-test, which includes four aspects: Head (knowledge), Heart (attitude), Hand (skills), and Harmony (harmony). Learning syntax starts with reflection, research, discovery, application, and communication (Laboy-Rush, 2010).

At the reflection stage, students are encouraged to understand the problem they will solve: environmental pollution caused by plastic food waste. Problems highlight the ability to think and behave (head & heart). The Research stage collects information from various sources, and the teacher delivers science learning. The teacher ensures that students understand the project they will make. The head, heart, and hand principles are applied at this stage. The next stage is application. At this stage, students carry out their project assignments to make eco-bricks and test the products they have made. Students learn to make connections between STEM disciplines. The final stage is communication. At this stage, students will communicate the ecobrick process and products. This stage is essential in learning to develop communication skills to build harmony.

Evaluation Stage

The development results were evaluated indirectly on the impact of using teaching materials in learning on student eco-literacy. The learning results show that the experimental class's Head aspect (knowledge) increased from 62.19% to 85.06%. This value is obtained from the results of the pre-test and post-test. The Heart aspect (attitude) increased from 60.3% to 87.43%. Hand aspect (skill) increased from 78.72% to 89.32%. The Harmony aspect rose from 54.35% to 86.03%. All elements of competency have increased after the implementation of PjBL-STEM 4H Ecobrick learning with an outstanding improvement category.

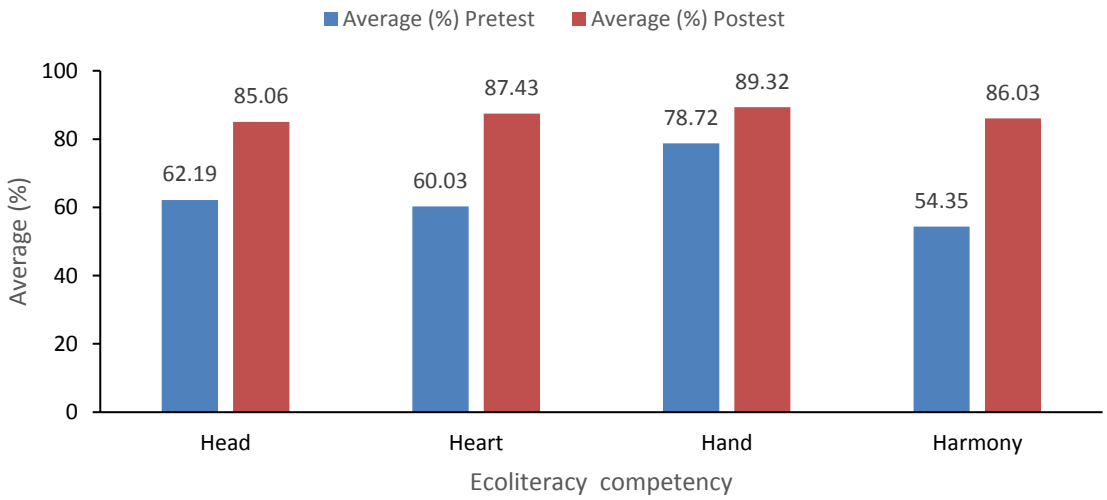


Figure 5. Ecoliteracy Competency Profile (4H)

An increase in the Head aspect indicates successful learning with PBL-STEM. This aspect can be understood because the head aspect closely relates to the student's competency/thinking skills. In the first step of STEM, students are invited to conduct an inquiry process by finding relevant concepts to solve problems. This indicator can be interpreted as saying that students have followed up the initial step of launching the problem by practising thinking that leads to analysis and argumentation. Questions asked by the teacher: "*How can you overcome pollution by plastic waste?*" directs students to discover what plastic is. *How is it made? Why is plastic waste dangerous?* and so on. Questions like that will become material for quite heated discussions among students in the group. These critical questions will ultimately lead students to critical thinking exercises. This statement is in line with what was stated by Dewi et al. (2023), Waluyo

(2023), and Purwasila (2024), which is that STEM learning can improve students' critical thinking skills.

In the next learning step, students are faced with a question: in front of us is a pile of plastic waste bottles. Guidance questions: *"What will you do with this plastic bottle waste?"*. This question will direct students in groups to think about how to turn waste into valuable products. By providing the necessary boundaries so that solutions are not too diverse, in the end, students are directed to create a creative idea related to changing waste into "something" that is useful. Questions like these then direct students to practice innovative thinking. They practice fluency, flexibility, and original and elaborate thinking skills. These aspects are indicators of creative thinking skills. The results of this research are in line with the results of previous research, which stated that STEM learning can improve creative thinking skills (Mardatillah & Kristeyulita, 2024; Nadihifah et al., 2024; Prastiwi & Sigit, 2024).

The hand aspect increases very well and is characterized by assessing creative products. Hand skills are closely related to creativity. Once again, it can be proven that STEM learning can accommodate creative exercises that awaken students' imaginations. The innovative products produced by students show that students have attempted to build their creativity without direction from the teacher. This aspect provides further scientific evidence that PBL-STEM can increase student creativity, as found in previous research (Rachmawati, 2024; Damayanti et al., 2024; Amriani et al., 2024).

Figure 6. Ecobrick Products Made by Students

The Heart and Harmony aspects are very closely related to the attitude aspect. This aspect of attitude is trained during PBL-STEM learning through efforts to build awareness of the environment, understand the need to protect the environment and create environmental awareness among other friends. By posing problems with an environmental context (the impact of plastic waste pollution on human life), learning is trying to build students' awareness of the need to maintain, overcome, and resolve environmental problems. PBL is a practical approach to fostering a positive learning environment. It equips students to think critically and analytically while encouraging them to explore various resources (Herzon et al., 2018). Additionally, PBL offers significant advantages for teachers, enhancing their creativity and innovation in delivering meaningful content in a

rapidly evolving science and technology landscape (Nasir et al., 2023). PBL stands out among other instructional models due to several key benefits. For instance, it helps students develop problem-solving skills and encourages them to tackle challenges within the academic context and everyday life. Furthermore, PBL promotes collaborative discussions and peer interactions, enabling students to conduct experiments to resolve issues (Handayani et al., 2022; Novianti et al., 2021).

However, PBL is not without its limitations. It may not be applicable across all subjects, making it particularly suited for lessons centred on problem-solving. Additionally, teachers may struggle to assign tasks effectively due to the diverse skill levels in a single class (Sulastry et al., 2023). The research results show that these two aspects develop well through learning. This result is in line with various previous research results on PBL-STEM. Raising environmental issues can build students' awareness and positive attitudes toward the environment (Indasari & Wulandari, 2024; Zana et al., 2024; Kamila & Muhsinah, 2024). In the end, if learning is carried out like this and produces good results for building 4H, then the goals of global education with education for sustainable development will become more accessible to achieve.

Conclusion

The product produced in this research is eco-literacy-based PjBL-STEM 4H Ecobrick teaching materials. The research results concluded that the teaching materials developed had met the appropriateness percentage score of 87.2% in the very valid category. The CVI and CVR indices of 0.995 and 0.990 are in the valid category. The teacher response to PjBL-STEM 4H Ecobrick learning materials was 90.05% in the outstanding category. The results of the implementation of PBL-STEM 4H Ecobrick teaching materials in learning in class 7A of SMPN 3 Cibadak, Sukabumi show effectiveness, which is in the outstanding category, because it can increase student eco-literacy.

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