

DEVELOPMENT OF STUDENT WORKSHEETS WITH CARBON FOOTPRINT OBJECT BASED ON PROBLEM-BASED LEARNING TO IMPROVE STUDENTS' CRITICAL THINKING SKILLS***Pengembangan Lembar Kerja Peserta Didik dengan Objek Jejak Karbon Berbasis Problem Based Learning untuk Meningkatkan Keterampilan Berpikir Kritis Peserta Didik*****Aisyah Zahrotul Islam**

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E-mail: winarsih@unesa.ac.id**Abstract**

Critical thinking skills are a competency that can be achieved through students' thinking processes that actual problem-solving processes can trigger. Problem-Based Learning (PBL) is one of the learning strategies that can focus students on solving problems independently to train higher-order thinking skills. This study aims to describe the validity, practicality, and effectivity of student worksheets with carbon footprint objects based on PBL to improve students' critical thinking skills. This development research used the Research and Development (R&D) method with the ADDIE procedure. The development of student worksheet was conducted at the Department of Biology, FMIPA UNESA, and applied to 35 X-7 SMAN 1 Sidoarjo students. Data collection techniques are interviews, validation, observation, tests, and questionnaires. The research instruments used were student worksheet validation sheets, implementation observation sheets, student response questionnaire sheets, pretest, and posttest assessment sheets, and critical thinking indicator achievement sheets. The data analysis technique used was the analysis of the validity implementation, student responses, learning completeness, and the achievement of indicators of critical thinking. The results are that the student worksheet with carbon footprint object based on PBL is stated to be very valid with a score of 3.8, declared very practical based on the implementation of student worksheet with a percentage of 97.8%, and very practical based on student responses with a percentage of 97.8%, and also declared effective based on mastery learning outcomes of 91% and effectively improve critical thinking skills of 86.7%.

Keywords: critical thinking, carbon footprint, problem-based learning, student worksheet**Abstrak**

Keterampilan berpikir kritis merupakan suatu kompetensi yang dapat dicapai melalui proses berpikir peserta didik yang dipicu oleh proses pemecahan masalah secara aktual. Problem Based Learning (PBL) menjadi salah satu strategi yang dinilai mampu memfokuskan peserta didik untuk menuntaskan masalah secara mandiri dalam pembelajaran sehingga melatih kemampuan berpikir tingkat tinggi. Adapun tujuan penelitian ini ialah untuk memaparkan efektivitas, praktikalitas, dan validitas LKPD dengan objek jejak karbon berbasis PBL untuk meningkatkan keterampilan berpikir kritis peserta didik. Penelitian ini termasuk penelitian pengembangan menggunakan metode Research and Development (R&D) dengan prosedur ADDIE. LKPD dikembangkan di Jurusan Biologi, FMIPA UNESA, dan diuji cobakan pada 35 peserta didik kelas X-7 SMAN 1 Sidoarjo secara terbatas. Pengumpulan data dilakukan menggunakan metode wawancara, validasi, observasi, tes, dan angket. Instrumen penelitian yang digunakan adalah lembar validasi LKPD, lembar observasi keterlaksanaan, lembar angket respon peserta didik, lembar penilaian pretest dan posttest, serta lembar ketercapaian indikator berpikir kritis. Analisis data pada penelitian ini menggunakan teknik analisis validitas LKPD, keterlaksanaan LKPD, respon peserta didik, ketuntasan belajar, dan ketercapaian indikator berpikir kritis. Dari penelitian ini, diperoleh hasil yaitu LKPD dengan objek jejak karbon berbasis PBL dinilai sangat valid dengan skor 3,8, sangat praktis jika dilihat dari keterlaksanaan sebesar 97,8% dan dari respon peserta didik sebesar 97,8%, serta dinilai efektif dilihat dari ketuntasan hasil belajar sebesar 91% dan mampu meningkatkan tingkat berpikir kritis sebesar 86,7%.

Kata Kunci: berpikir kritis, LKPD, jejak karbon, problem-based learning.

INTRODUCTION

One of the efforts to develop character and cultivate knowledge is obtained from education that is applied early on to students. Quality education can increase the opportunities and hopes of students to live a more meaningful life. Good quality education must involve students' activeness in changing their conditions, such as prioritizing student involvement in direct learning (Chasanah et al., 2016). Kristiyanti (2022) argues that in this 21st-century era, students can acquire learning skills through standard educational processes.

Four student abilities are focused on in 21st-century learning: the ability to communicate, think creatively, innovatively, collaborate, think critically, and solve a problem (Rahayu & Budiyo, 2018). Law no. 20 of 2003, article 1, paragraph 1, which defines education as a conscious effort of students to realize the learning process and atmosphere to actively implement self-potential development, spiritual, religious, personality, intelligence, self-control, skills, and noble character that is needed by themselves, society, nation, as well as the country.

In 2022, Indonesia's education curriculum will change from the 2013 Curriculum (K-13) to the Free Learning Curriculum. Freedom to learn is a breakthrough policy released by the Minister of Education, Nadiem Makarim, to return the authority to manage education for school principals and local governments (Sutanto, 2020). Education in the current era of independent learning can provide many opportunities in efforts to develop student's critical thinking skills (N. A. Kurniawan et al., 2020).

Hidayat et al. (2019) define the ability to think critically as the ability to think using deep reasoning in order to obtain appropriate information that can be accounted for. The importance of critical thinking skills is also related to their decision-making skills so that they become provisions-life skills in the future (Rahmawati et al., 2019). Facione (2013) states that the criteria or indicators of critical thinking skills are divided into six aspects, namely interpretation, analysis, inference, explanation, evaluation, and self-regulation. In this research, researchers focused on improving three indicators: analysis, explanation, and inference.

There is a tendency for students to start thinking processes, namely difficulty understanding due to lack of prior knowledge, ineffective use of teaching materials or media, or even inappropriate learning models, such as students will only get explanations by listening to the teacher in class. It causes students' critical thinking to

develop, and the learning process is still focused on remembering and memorizing.. In addition, according to Ningsyih et al. (2016), currently, the problem that occurs is that students tend to prefer memorizing the material presented by the teacher rather than searching for information independently, so their level of critical thinking is still relatively low, and needs to be developed.

The concept of critical thinking and understanding of the cognitive aspects are closely related, where when a problem related to the quality and feasibility of research is solved, or a solution is sought in terms of the cognitive and conceptual aspects, it is carried out to find out the developments that occur in the process of critical thinking. The achievement of learning goals properly requires a model in the learning process (Fauzia, 2018). Critical thinking skills can be optimized through problem-based learning or Problem Based Learning (Azizah, 2020).

In developing 21st-century learning, teachers are required to create learning processes in a student center where students are required to be active so that teaching and learning activities aim to give students more motivation and interest during learning. Therefore, teachers are expected to be able to develop learning tools such as student worksheet with innovative learning models. It can stimulate and involve students more actively in discussing learning material so that they gain experience and are not limited to mere knowledge (Rahayu & Budiyo, 2018).

In the implementation, it has characteristics that align with the standards of the Independent Curriculum, where students are expected to be able to think critically and have the initiative in responding to issues related to the development of Biology in people's lives. The existence of experimental activities as a form of scientific work based on a scientific attitude by involving process skills can teach and familiarize students with scientific truths. Logical thinking based on the reality on the ground can facilitate students' thinking process based on the thought of analyzing a problem.

Global warming is one of the many environmental issues currently being highlighted. Global warming is a phenomenon of increasing global temperatures triggered by human activities, which can cause the emission of greenhouse gases, which are increasingly filling the atmosphere (Triana, 2008). According to World Meteorological Organization (WMO), 2015 became the hottest year ever to hit the world due to global warming and the El Nino dry climate in the Pacific region. The WMO also stated that the earth's average temperature in

2015 was one degree Celsius higher than in the pre-industrial era.

Global warming, which caused significant changes to the climate in 2015, has worried the world's citizens. So a meeting of several countries or also called the 21st climate negotiations (COP 21) of the UN Framework Convention, was held in the context of world climate changes took place in Paris. The Paris Agreement aims to reduce the heat in the Earth's atmosphere by 20Celsius. As one of the ratifying countries, Indonesia has stated that it will actively reduce gas emissions to prevent global climate change. The Paris Agreement also makes forests the most crucial element in all forms of efforts to reduce gas emissions because the function of forests in absorbing greenhouse gasses is very high. In this case, Indonesia has a vital role for the world in suppressing the increase in the Earth's temperature; where Indonesia has been named the owner of the second-largest number of forests in the world.

One of the human activities that can trigger a high carbon footprint in the air is the use of motorized vehicles. The carbon footprint is a measure that includes the total amount of carbon dioxide emissions resulting from excessive human activity from the various products used in daily life. The more people there are, the more energy will be used, causing a high carbon footprint in the air (Negoro et al., 2021).

Problems with environmental issues related to carbon footprint The items are included in the sub-material of environmental change in learning with the Free Learning Curriculum mentioned in the Learning Outcomes (CP). The learning outcomes that are the reference for researchers are at the end of phase E, where students are directed to become active in responding to various global issues and solving problems to create capabilities in terms of observation, planning, research, data analysis, predicting, evaluating, reflecting, and communicating simple projects with the help of technology. Several topics can be applied in this phase, one of which is global warming and environmental pollution. This phase can develop students' knowledge, namely being honest, having critical reasoning, cooperative, scientific attitude, and global diversity.

Based on the results of interviews with biology teachers at SMAN 1 Sidoarjo, class X students need to apply a problem-based learning model so that students' critical thinking skills increase from before. This research's problem is the validity, practicality, and effectiveness of using student worksheets with carbon footprint objects based on problem-based learning to improve students' critical thinking skills. This study aims

to determine the validity, practicality, and effectiveness of using student worksheets with carbon footprint objects based on problem-based learning to improve students' critical thinking skills.

The researcher also developed worksheets based on the Merdeka Learning curriculum that is currently in effect. With hope, through student worksheet based Problem Based Learning With this carbon footprint object, researchers want students to be able to find out the level of the carbon footprint they produce when using motorized vehicles as transportation to school every day by calculating the carbon footprint presented in the student worksheet so that students can solve environmental issues by estimating impacts as well as solutions. Simple steps can apply to reduce carbon footprints and minimize ongoing global warming. Through this problem-solving process, students' critical thinking skills are expected to increase, especially in the indicators of analysis, explanation, and inference.

Based on this background, the researcher wants to design a development study with the research title "Development of Student Worksheets with Carbon Footprint Objects Based on Problem-Based Learning to Improve Students' Critical Thinking Skills."

METHODS

This research includes study development, where researchers want to develop student worksheets with carbon footprint objects based on problem-based learning to improve students' critical thinking skills. This type of research is quantitative research using research and development (R&D) methods. According to Sugiyono (2016) in Prihatiningsih et al. (2017), the R&D method is an approach to improve previous products or produce new product findings. This method consists of ten stages, but in this study, it was only carried out until the sixth stage. This study uses the ADDIE procedure without going through the implementation phase.

This student worksheet was developed at the Biology Department in December-April 2023, and a limited trial process of implementing student worksheet was carried out at SMAN 1 Sidoarjo for the 2022/2023 academic year in May 2023. The trial of the student worksheet that had been developed was limited to all classes X- 7 SMA Negeri 1 Sidoarjo for the academic year 2022/2023, with a total of 35 students consisting of 15 students and 20 female students. Technique sampling saturation is a sampling technique where samples are taken from all population members, and generalizations are carried out with a relatively low error rate (Sugiyono, 2017).

At the analysis stage, there are curriculum analysis and student analysis. The analysis stage is defined as the stage of determining the problem as well as the right solution (Siregar, 2019). Curriculum analysis is based on the Merdeka Belajar Curriculum on the sub-material of environmental change, with the aspects analyzed, including learning outcomes and the profile of Pancasila students, to be achieved using student worksheets. Student analysis includes analysis related to the needs and backgrounds of students.

At the design stage, researchers compiled student worksheets by preparing learning tools and student worksheets designs by the Merdeka Curriculum. The process of designing student worksheets is carried out by determining learning objectives, learning methods, strategies, and teaching materials, according to the results of the needs analysis that has been done before. The design phase contains systematic planning, outlines, selects formats, media, and drafts (Hanida et al., 2023).

At the development stage, the researcher produces worksheets that will be used in learning according to the design that was previously made at the design stage. The student worksheet made will then go through a validation process by the validator. Student worksheets was tested in limited trials with a research design One-Group Pretest-Posttest Design, that is, before being given treatment will be carried out measuring the initial knowledge of students first using a pretest. Measurements were taken at the end of using the post-test. The test was only carried out in one class, so the results obtained were more accurate because there was a direct comparison between the conditions before and after treatment. The treatment used in this research is the use of student worksheets with carbon footprint objects based on problem-based learning to improve students' critical thinking skills.

The design and development stages carried out previously can be realized through an implementation activity. According to Siregar (2019), the purpose of this implementation stage which is in line with this research is to guide students in achieving competencies or learning objectives, guaranteeing problem-solving and analysis of solutions in order to improve student learning outcomes by using a problem-based learning model, namely Problem-Based Learning, as well as guaranteeing the achievement of attitudes, skills and knowledge competencies of students at the end of learning where in this study focuses on increasing the achievement of indicators of critical thinking.

Product design and development results produce valid and feasible LKPD to be tested based on the LKPD

validation process. Furthermore, LKPD can be applied through limited trials to 35 students to determine the practicality and effectiveness of learning.

The evaluation stage, according to Siregar (2019), aims to assess the level of effectiveness of a lesson by looking at student learning outcomes. Evaluation stages for each learning component are needed to obtain a complete and clear picture of the quality of the learning. At each stage of product design, namely analysis, design, and development, evaluation activities are needed to produce a product with good quality.

The research variables used include the validity, practicality, and effectiveness of worksheets with PBLbased carbon footprint objects in increasing students' critical thinking skills, which are limited to three indicators: analysis, explanation, and inference. The instruments used included student worksheet validation sheets, implementation observation sheets, student response questionnaire sheets, pretest and posttest assessment sheets, and critical thinking indicator achievement sheets.

Data collection in research development worksheets with carbon footprint objects was carried out using interview methods, validation methods, observation methods, student response questionnaire methods, and test methods according to indicators of critical thinking so that the level of critical thinking can be measured based on indicators of analysis, explanation, and inference.

The validity of student worksheets is reviewed based on validation by validators, namely education expert lecturers, subject matter expert lecturers, and biology teachers (Lette & Kuntjoro, 2019). The instrument used in determining the validity of student worksheets is in the form of validation sheets which are reviewed from aspects of theoretical feasibility, namely from presentation aspects, linguistic aspects, and content feasibility aspects (R. Kurniawan, 2021). The validity sheet questionnaire uses the Scale guidelines Likert 1-4, namely categories 1 (poor), 2 (fair), 3 (good), and 4 (very good). Furthermore, calculations are performed on the validation scores of the three validators that have been obtained using the following formula:

$$\text{Average score} = \frac{\sum \text{score from each aspect}}{\text{number of validators}} \dots\dots\dots(1)$$

From the average score that has been obtained, then an analysis is carried out with the following formula to obtain the overall validation average score:

$$\text{Average score} = \frac{\text{average score of each aspect}}{\text{number of aspects assessed}} \dots\dots\dots(2)$$

According to the eligibility of the student worksheet, where it is declared valid if it gets a score ≥ 2.5 with interpretation in the following table:

Table 1. Criteria for interpreting the validity of student worksheet according to Riduwan (2013)

Average Score	Interpretation
1.00-1.75	Not valid
1.76-2.50	Less valid
2.51-3.25	Valid
3.26-4.00	Very valid

The practicality of student worksheets in terms of the responses of students and the implementation of student worksheet during biology lessons (Wulandari & Novita, 2018). Scale Gutman with an assessment score of 1 for "Yes" and 0 for "No" as a reference in the implementation observation sheet and student response questionnaire. The calculation results of the student worksheet practicality score will be obtained using the following formula:

$$\text{Implementation (\%)} = \frac{\sum \text{score for "Yes"}}{\text{max score}} \times 100\% \dots (3)$$

The percentage of observation results is then interpreted using the eligibility criteria; the student worksheet is implemented well if the percentage of implementation is obtained at $\geq 61\%$ according to the interpretation of the data listed in the following table:

Table 2. Criteria for interpreting the implementation of student worksheet according to Riduwan (2013)

Score (%)	Interpretation
0-20	Very impractical
21-40	Not practical
41-60	Practical enough
61-80	Practical
81-100	Very practical

Analysis of the effectiveness of student worksheets in terms of completeness of learning outcomes and achievement of indicators of critical thinking, in which the completeness of learning outcomes is assessed from the acquisition of results pretest and posttest, where student worksheets can be declared effective if the value posttest experienced a significant increase in value pretest or the acquisition of students' scores above KKM in Biology class X SMA Negeri 1 Sidoarjo is at least 75 so that the standard used to determine the completeness indicator is if the overall average score is ≥ 75 . The student worksheet that has been developed is declared effective if the students who complete one class are $\geq 70\%$ in the excellent category. The percentage of

completeness of students in one class can be found using the formula:

$$\text{Completeness (\%)} = \frac{\sum \text{student who complete}}{\text{number of students}} \times 100\% \dots (4)$$

To find out the increase of pretest and posttest can be done by counting N-gain. The formula used is as follows:

$$\text{N-gain} = \frac{\text{posttest score} - \text{pretest score}}{\text{max score} - \text{pretest score}} \dots (5)$$

The calculation results from N-gain are then grouped based on high, medium, and low levels. The following is the score interpretation criteria n-gain:

Table 3. Criteria of interpreting n-gain scores by Riduwan (2013)

N-gain normalized	Interpretation
$g < 0.3$	Low level
$0.7 > g \geq 0.3$	Medium level
$g \geq 0.7$	High level

The effectiveness of student worksheets was assessed based on the achievement of three indicators: analysis, explanation, and inference obtained from consideration using the following formula:

$$\text{Achievement (\%)} = \frac{\sum \text{score each indicators}}{\text{max score}} \times 100\% \dots (6)$$

The percentage results that have been obtained are then interpreted in the following table:

Table 4. Criteria for interpretation of the achievement of critical thinking indicators according to Setyowati & Subali (2011)

Score (%)	Interpretation
$0 < P \leq 43.75$	Very low
$43.75 < P \leq 62.5$	Low
$62.5 < P \leq 71.5$	Medium
$71.5 < P \leq 81.25$	High
$81.25 < P \leq 100$	Very high

Student worksheet is declared effective if the percentage of students' critical thinking skills scores $\geq 71.5\%$ with high category.

RESULT AND DISCUSSION

This development research produces student worksheets with carbon footprint objects based on problem-based learning to improve students' critical thinking skills. This student worksheet was developed to improve students' critical thinking skills, focusing on three indicators: analysis, explanation, and inference. The achievement of the research objectives was assessed based on the student worksheet feasibility test based on

the results of its validity, practicality, and effectiveness. This student worksheet consists of six activity points that students must follow and do, including “Mari Menyimak Video!”, “Mari Menghitung Jejak Karbonmu!”, “Mari Menghitung Daya Serap Pepohonan!”, “Mari Menghitung Sisa Emisi Karbondioksida!”, “Mari Menyajikan Hasil!”, and “Mari Menyimpulkan!”. These six points contain three indicators of critical thinking that want to be improved, namely indicators of analysis, explanation, and inference. In addition, the student worksheet contains all phases of Problem Based Learning.

Validity of Student Worksheet

The results of the validation test assessment by three validators cover three aspects, namely the content feasibility aspect, the presentation aspect, and the language aspect. The results of the recapitulation of the validity of the student worksheet are presented in the following table:

Table 5. Recapitulation of student worksheet's validation results by three validators

Results by three validators					
	Criteria	Score			
		V1	V2	V3	Average
Presentation Aspect					
1	Title				
	The suitability of the title with the material	4	4	3	3.67
	The meaning of the title	4	4	4	4
	Layout of title	4	4	4	4
2	Time Allocation				
	Appropriateness of the time allocation given for carry out activities in student worksheet	3	4	3	3.3
3	Learning aims				
	There are learning aims in student worksheet	3	3	3	3
	Suitability of learning aims and the material	3	4	3	3.3
4	Questions				
	Compatibility of questions in student worksheet with learning aims	4	4	4	4
	Clarity of questions in student worksheet	4	4	4	4
5	Presentation				
	The appearance of student worksheet	4	3	4	3.67
	Systematic way of presenting student worksheet	4	4	4	4
	Letter appearance of student worksheet	3	4	4	3.67
	Language that used in student worksheet	4	4	4	4
	Structure of the sentences in student worksheet	4	4	4	4
	Clarity of instructions in student worksheet	4	4	3	3.67
Average					3.73
Interpretation					Very valid
Linguistic Aspect					

1	The use of language arrangement is appropriate by PUEBI	4	4	4	4
2	Sentences are meaningless double	4	4	4	4
3	Sentences do not contain elements of SARA	4	4	4	4
4	Sentences used are clear and operational	4	4	4	4
5	Language used operational	4	4	4	4
Average					4
Interpretation					Very valid
Content Eligibility Aspect					
1	Systematic summary of material in student worksheet	4	4	3	3.67
2	Suitability of the summary of the material with the learning aims	3	4	3	3.3
3	Conformity of the material with the truth of the concept	4	4	4	4
4	The function of the material summary in achieving the learning aims	3	4	3	3.3
5	Summary equipment material in student worksheet	4	4	4	4
6	Includes phase execution Problem Based Learning	4	4	4	4
7	Includes achievement of critical thinking indicators	4	4	4	4
Average					3.76
Interpretation					Very valid
Average of all aspects					3.83
Interpretation					Very valid

Information on the interpretation of the student worksheet validity score: 3.26-4.00 = very valid; 2.51-3.25 = valid; 1.76-2.50 = quite valid; 1.00-1.75 = less valid.

Three aspects are assessed in the student worksheet validation process: presentation aspects, language, and content feasibility (R. Kurniawan, 2021). The validity of the student worksheet based on the presentation aspect obtained a score of 3.73, indicating that the presentation on the student worksheet was very valid. However, there are still deficiencies in this aspect of student worksheet presentation, so it has yet to receive a score of 4, where there is a discrepancy in the time allocation contained in student worksheet with the implementation of student worksheet activities. This is possible because, during the implementation of the activity, there is still a possibility that the time allocation used in the student worksheet may change and be conditional. The learning aims in student worksheet are still not by the subject matter, where the number of learning objectives is too large and less concise, and the learning objectives at the two meetings should be distinguished. This can make it easier for teachers to carry out a series of lessons and be more structured at each meeting.

Regarding appearance, there are also deficiencies in student worksheet, where the colors are not bright enough. However, despite deficiencies in appearance, the

student worksheet is still categorized as feasible and attractive. Susantini (2016) explained that a textbook could attract students' attention so that the entire content or material in the book can be digested properly. The clarity of the instructions listed in the student worksheet is also not perfect, especially at the point "Let's Calculate the Absorption Capacity of Trees!" those related to the identification of trees in the school parking area still do not include the characteristics of trees that can be classified as tree species that can be counted in the calculation of absorption capacity. It could make students confused so that they make mistakes in the process of identifying tree species. Thus, the student worksheet has fulfilled the assessment on the presentation aspect with a very valid category.

The validity results based on linguistic aspects get a score of 4 with a very valid category. The validator considers that the use of language and the arrangement of sentences in the student worksheet are by the General Guidelines for Indonesian Spelling (PUEBI). Widjajanti (2008) argues that linguistic aspects and sentences that are well used in student worksheet must have clarity and suitability of the language used with the maturity level of students so that language or sentences become easier to understand. Thus, the student worksheet has fulfilled the assessment on the linguistic aspect with a very valid category.

The eligibility of the contents of the student worksheet states that the material and subject matter listed in the student worksheet are by the indicators, concepts, and learning objectives to be achieved with a score of 3.76 and is declared very valid. Even so, in the aspect of content feasibility, there are still deficiencies in the summary of the discussion, which is not in sync with the learning objectives, where the summary contained in the student worksheet contains more carbon footprint calculation formulas only, so there is less explanation or supporting materials related to the discussion of carbon footprints that are more in line with biology learning. However, at the point of implementation, Problem-Based Learning student worksheet is stated to be very valid because it already contains five PBL phases, namely student orientation to problems, organizing students to learn, guiding individual and group investigations, presenting work, and analyzing and evaluating problem-solving processes. Each of these phases has been listed in each activity in the student worksheet. student worksheet has also reflected the three indicators of critical thinking skills that want to be improved: analysis, explanation, and inference. Prastowo (2015) argues that student worksheet contains essential aspects related to discussion

and instructions for using student worksheet in working on related item items.

Practicality of Student Worksheet

The practicality of students' worksheets with carbon footprint object based on Problem-Based Learning based on the results of observations of implementation by observers and student responses (Wulandari & Novita, 2018). Observation of the implementation of learning using student worksheet was observed by three observers using the student worksheet implementation observation sheet. Observation of the implementation of student worksheet was carried out twice. At the first meeting, which contained 13 student activities that needed to be observed, and at the second meeting, which contained four student activities that needed to be observed, where each meeting had a time allocation of 3 lesson hours or 3x45 minutes. student worksheet implementation data is described in the following table:

Table 5. Recapitulation of the results of observing the implementation of student worksheet

Implementation of Student Worksheet				
No	Observation Aspects	Percentage (%)		Interpretation
		Yes	No	
First Meeting				
1	Students read learning objectives	97.1	2.9	Very practical
2	Students understand instructions listed on the student worksheet	100	0	Very practical
3	Students read time allocation on student worksheet	97.1	2.9	Very practical
4	Students understand summary material discussion	100	0	Very practical
5	Phase 1 PBL Students watch that video served and answer the question related video found in the worksheet (Analysis)	91.4	8.6	Very practical
6	Phase 2 PBL Students assemble accordingly group that has specified for work on worksheet	100	0	Very practical
7	Phase 3 PBL Students identify type which vehicle members use current group go to school and serve it in table (Analysis)	94.3	5.7	Very practical
8	Phase 3 PBL Students calculate distance (in kilometers) that taken from the gate to the	94.3	5.7	Very practical

	parking lot school (Explanation)			
9	Phase 3 PBL Students do the calculations carbon emissions in group (Explanation)	94.3	5.7	Very practical
10	Phase 3 PBL Students identify type trees around the school area (Analysis)	100	0	Very practical
11	Phase 3 PBL Students do the calculations absorption capacity of trees (Explanation)	100	0	Very practical
12	Phase 3 PBL Students analyze the calculated data obtained and answer the question in student worksheet (Analysis)	100	0	Very practical
13	Phase 3 PBL Students summed up the results data analysis (Inference)	100	0	Very practical
Average (%)		97,6		Very practical
Second Meeting				
1	Phase 4 PBL Students do presentation in front of the class (Explanation)	100	0	Very practical
2	Phase 4 PBL Students listen and respond to presentations another group	100	0	Very practical
3	Phase 5 PBL Students reflect that learning has been going on by writing the result of that experience obtained from student worksheet	97.1	2.9	Very practical
4	Phase 5 PBL Students submit their independent task that listed in the appropriate worksheet from the previous meeting	94.3	5.7	Very practical
Average (%)		97.9		Very practical
Average from all meeting		97.8		Very practical

Interpretation of the student worksheet implementation score (%): 0-20 = very impractical; 21-40 = impractical; 41-60 = quite practical; 61-80 = practical; 81-100 = very practical.

The practicality of student worksheet is obtained from the implementation and responses of students to the use of student worksheet in learning (Wulandari & Novita, 2018). According to Wati dan Yuliani (2020), the implementation of student worksheet can be indicated through learning activities that are carried out using the previously developed student worksheet. From the data obtained, the average percentage of implementation at the first meeting was 97.6%, and at the second meeting was 97.9%, so an overall average percentage was obtained of 97.8%. This score indicates that student activities using the developed student worksheet can be categorized as very practical (Riduwan & Sunarto, 2013).

In the learning model Problem-Based Learning, five phases are used in each student activity using student worksheet. The first phase is the orientation of students towards the problem by providing stimulation in the form of a YouTube video, which must be analyzed by students by answering questions related to the video, which reflects the analysis indicators obtaining a percentage of 91.4% and is stated to be very practical. From this, students can recognize and describe and explain a problem. In the second phase, namely organizing students to study where students are directed to gather with their respective groups that have previously been arranged to discuss student worksheet, they get a percentage of 100% and are declared very practical. The third phase guides individual and group investigations, where all activities reflecting the third phase are categorized as very practical. Students are assessed as able to prove through an experiment and test the truth, where students identify tree species and vehicles that reflect analysis indicators, calculate the distance from the school gate to the parking lot, calculate carbon gas emissions, and calculate the absorption of trees that reflect explanation indicators, analyze calculated data reflecting analysis indicators, as well as making conclusions from data analysis reflecting inference indicators. Students can better understand the concept through a problem, or event observed about the studied object (Wati & Yuliani, 2020).

In the fourth phase, namely presenting the work results, reflecting the explanation indicators obtained a percentage of 100% in the very practical category, where students can present group discussions and respond to each other, answer, and express their opinions. Through presentation activities, students become more motivated to interact with each other and convey arguments so that students can dig deeper into information related to the material. The final phase is analyzing and evaluating the

problem-solving process by reflecting on learning and writing down the results of each experience, obtaining a percentage of 97.1% and being declared very practical, and students collecting independent assignments obtaining 94.3% and being declared very practical.

Overall, the average percentage of student worksheet implementation obtained from the two meetings is very practical. According to Saputra (2019), Problem-Based Learning able to raises real problems and information to develop critical thinking skills. Problem-Based learning is learning that focuses on the process of solving problems that originate from everyday life. Students can interact directly with learning resources and find information or concepts independently by utilizing the surrounding environment. This is in line with the formulation of the Ministry of Education and Culture regarding learning in the 21st century, which focuses more on the ability to formulate problems, think logically, dig up student information from various sources, and work together.

The practicality of student worksheets is also seen from the students' positive responses, where the student response questionnaire includes three aspects: language, presentation, and display.

Table 6. Recapitulation of the results of student responses to student worksheet

No	Questions	Percentage (%)		Interpretation
		Yes	No	
Linguistic Aspect				
1	Is the language in student worksheet use Indonesian that good and right?	100	0	Very practical
2	Are that sentences easy to understand?	94.3	5.7	Very practical
3	Is the inscription in student worksheets read clearly?	100	0	Very practical
Average percentage (%)		98.1		Very practical
Presentation aspect				
4	Are the learning aims in this student worksheet easy to understand?	97.1	2.9	Very practical
5	Are any instructions activities on student worksheet clear, understandable, and integrated?	91.4	8.6	Very practical
6	Are the answer columns provided sufficient to load answers?	91.4	8.6	Very practical
7	Are the sentences listed in the student worksheet easy to read?	100	0	Very practical
8	Can you identify the issue of environmental-	97.1	2.9	Very practical

	related carbon footprint correctly?			
9	Can you understand the way to calculate your carbon footprint correctly?	94.3	5.7	Very practical
10	Can you understand the way to calculate absorption trees around correctly?	97.1	2.9	Very practical
11	Can you understand the simple effort to cope with high carbon emissions?	100	0	Very practical
Average percentage (%)		96.05		Very practical
Display aspect				
12	Is the display of the worksheet attractive?	100	0	Very practical
13	Is the font and font size in worksheet can be read clearly?	100	0	Very practical
14	Is the whole student worksheet exciting and fun?	97.1	2.9	Very practical
15	Is the color that uses in student worksheet suitable?	100	0	Very practical
Average percentage (%)		99.3		Very practical
Average of all aspects (%)		97.8		Very practical

Interpretation of the student worksheet implementation score (%): 0-20 =very impractical; moderate; $g < 0.3$ = low 21-40 = impractical; 41-60 = quite practical; 61-80 = practical; 81-100 = very practical.

The language aspect obtained a percentage of 98.1% and was stated to be very practical. Therefore, the language and sentence structure used in student worksheet is considered straightforward and easy to understand. Widjajanti (2008) argues that linguistic aspects and sentences that are well used in student worksheet h the maturity level of students so that language or sentences become easier to understand. In the presentation aspect, the assessment is based on the clarity of learning objectives, instructions, readability of sentences, availability of answer columns, and student's understanding of the material in student worksheet as a whole, obtaining a percentage of 96.05% in the very practical category. The display aspect gets a percentage of 99.03% in the very practical category. The display aspect includes students' interest in student worksheet in terms of color display, use of effects, font type, and font size. As explained by Susantini (2016) a textbook can be categorized as good if it can attract students' attention so that students can better understand the contents of a book. Therefore, as a whole, based on the average of these three aspects, students' responses to the use of worksheets with carbon footprint objects based on

Problem Based Learning rated positive and obtained an overall average percentage of 97.8% in the very practical category.

Effectivity of Student Worksheet

The effectiveness of using student worksheet is based on the completeness of the assessment results from the pretest and posttest and the achievement of three indicators of critical thinking skills (Wulandari & Novita, 2018) namely analysis, explanation, and inference.

Table 7. Recapitulation of completeness of student learning outcomes

Aspects	Pretest	Posttest
Class average	50	87
Completeness percentage class	8.6%	91%
Interpretation of the completeness	Not complete	Complete
Average of <i>N-gain</i>	0.73	
Category	High	

Category description of *n-gain*: $g \geq 0.7$ = high; $0.7 > g \geq 0.3$ = moderate; $g < 0.3$ = low

Completeness of learning outcomes obtained from the assessment pretest and posttest given before and after working on the student worksheet by students, where are the questions pretest and posttest contains 5 items description questions. Based on the data obtained, on pretest obtained an average class value of 50 with a completeness of 8.6%, and at posttest obtained an average class value of 87 with a completeness of 91% so that an average of *n-gain* is obtained 0.73 with the high category

In addition to using value data Pretest and Posttest, the effectiveness of student worksheet with carbon footprint objects based on Problem-Based Learning can also be known through the achievement of indicators of critical thinking skills, where three indicators are used: explanation, analysis, and inference.

Table 8. Recapitulation of achievement indicators of student's critical thinking

Indicators	Pretest		Posttest	
	Completeness (%)	Category	Completeness (%)	Category
Explanation	45.8	Low	88.5	Very high
Analysis	25.8	Very low	88.5	Very high
Inference	22.8	Very low	83	Very high
Average of completeness indicators (%)	31.5		86.7	
Category	Very low		Very high	
Interpretation of completeness	Not complete		Complete	

Description of the category percentage of achievement indicators: $0 < P \leq 43.75$ = very low; $43.75 < P \leq 62.5$ = low; $62.5 < P \leq 81.25$ = high; $81.25 < P \leq 100$ = very high.

Increasing the score on each indicator of critical thinking, where the explanation indicator is on the pretest has a completeness of 45.8% with a low category and an increase in value posttest 88.5% with a very high category. Analysis indicators on the pretest have a completeness of 25.8% with a very low category and have increased in the posttest 88.5% with a very high category. The inference indicator on the pretest has a completeness of 22.8% with a very low category, and there is an increase in value posttest 83% and declared very high category.

Overall, student worksheet can be assessed as improving learning outcomes and students' critical thinking skills by acquiring pre- and post-test grades. This increase occurred because the learning model is Problem-Based Learning that centered on students so that students are taught to be independent in finding concepts and solving problems. Mulyasa's statement (2014) is by these results, namely in the acquisition results pretest and posttest used to calculate the increase in students' critical thinking skills through a comparison. Full student involvement, cooperation, and student independence in understanding learning are considered to improve critical thinking skills (Karim et al. 2018).

Students' thinking activeness can be achieved with a problem-based model so that students' understanding and experience become more developed in writing, reading, listening, and speaking due to their involvement in thinking and gathering information (Florea & Hurjui, 2015). The achievement of critical thinking indicators can also be indicated by students who can train themselves by orienting students to problems, organizing students to learn, guiding individual and group investigations, presenting work, and analyzing and evaluating the problem-solving process of all activities in student worksheet who apply the learning model Problem-Based Learning. Learning to use the problem base is considered very effective in facilitating students in finding solutions to problems because both are directly related to students' daily lives naturally (Drăghicescu et al., 2014). With this PBL-based student worksheet, students can develop skills to ask, answer, and observe the material being studied. Therefore, based on the learning outcomes (Pretest and Posttest) and the achievement of critical thinking indicators, student worksheet with carbon footprint objects based on

Problem-Based Learning was declared effective in increasing critical thinking.

CLOSING

Conclusion

Based on the overall research results that have been described from the formulation of the problem, research objectives, and research results to the discussion, conclusions are obtained that student worksheets have been produced with PBL-based carbon footprint objects to improve proper critical thinking skills based on the results of validity, practicality, and effectiveness. Student worksheet was stated to be very valid with an overall average score of 3.83 based on the results of validation by the validator, very practical when viewed from the implementation of 97.8% and the student response of 97.8%, and was considered effective in terms of the completeness of the learning outcomes of 91% and able to increase the level of critical thinking by 86.7%.

Suggestion

This research includes research on the development of student worksheet, which is still being tested and limited, so further application research is needed to know the effectiveness of learning using the student worksheet that has been developed. The main object in this student worksheet focuses more on the process of calculating carbon gas emissions produced by students in their daily lives, so it is hoped that in future research, more material or content can be provided on the relationship between carbon footprint and environmental change, climate change, and global warming on earth's living things.

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