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Development of a Multiple Representation-Containing Students' Worksheet Integrated with Problem-Based Learning to Improve Students' Critical Thinking Skills on the Hydrocarbon Topic

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ABSTRAK

Penelitian pengembangan ini bertujuan untuk menghasilkan LKPD bermuatan multirepresentasi terintegrasi Problem Based Learning yang layak, efektif, dan memperoleh respon dari peserta didik setelah menggunakan LKPD tersebut. Metode yang digunakan dalam penelitian ini menggunakan metode Research and Development dengan model penelitian yaitu 4-D yang meliputi define, design, develop, dan disseminate. Kelayakan LKPD dapat dilihat melalui penilaian validator ahli yang menilai lembar validasi ahli materi dan ahli media dengan rata-rata hasil validasi yang diperoleh secara berturut-turut sebesar 88,59% dan 90,41% dengan kategori sangat layak, serta dilakukan uji keterbacaan dan diperoleh nilai sebesar 88,33% dengan kategori sangat baik. Berdasarkan hasil penilaian validasi ahli dan keterbacaan menunjukkan LKPD yang dikembangkan layak untuk digunakan pada pembelajaran materi hidrokarbon. Keefektifan LKPD dapat dilihat dari hasil nilai Wilcoxon yang diperoleh melalui nilai pretest dan posttest peserta didik untuk mengetahui adanya peningkatan signifikan atau tidak pada keterampilan berpikir kritis peserta didik, serta uji Effect Size untuk mengetahui persentase dari peningkatan tersebut dan diperoleh nilai sebesar 0,876 dengan efektivitas tinggi. Berdasarkan hasil uji efektivitas menunjukkan LKPD yang dikembangkan efektif dalam meningkatkan keterampilan berpikir kritis. Hasil respon peserta didik memperoleh persentase sebesar 85,33% dengan kategori sangat menarik. Hasil penelitian menunjukkan LKPD bermuatan multirepresentasi terintegrasi PBL terbukti mampu meningkatkan keterampilan berpikir kritis peserta didik pada materi hidrokarbon.

ABSTRACT

The goal of this research study is to develop a feasible and effective multiple representation-containing students' worksheet integrated with Problem-Based Learning that receives feedback from students. This research uses the R&D method with the 4-D research model, which includes define, design, develop, and disseminate. The feasibility of the students' worksheet is evident through the expert validators' assessment of the material and media experts' validation sheets, with average validation results of 88.59% and 90.41%, respectively, categorized as highly feasible. Additionally, a readability test was conducted, yielding a score of 88,33%, which is categorized as "very good". Based on the expert validation and readability assessment results, the developed students' worksheet is suitable for teaching the hydrocarbon topic. The students' worksheet effectiveness can be seen in the Wilcoxon test results, which were obtained from the students' pretest and posttest scores to determine if there was a significant improvement in their critical thinking skills. The Effect Size test yielded a value of 0,876, indicating high effectiveness. Based on these results, the students' worksheet is effective in improving critical thinking skills. Students' responses yielded a percentage of 85.33%, categorized as "very interesting." The results showed that a multiple-representation-containing students' worksheet integrated with Problem-Based Learning content improves Students' Critical Thinking Skills on the Hydrocarbon topic.

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INTRODUCTION

Education continues to develop, and there are always changes over time. From year to year, education is adjusted to the needs of the times, so that education must remain relevant to the conditions of society. Nowadays, the development of technology is accelerating and makes it easier for us to do any work. However, if the benefits are not used properly, they will backfire on you. Therefore, in 21st-century skills, students are expected to be able to adjust and be wise in utilizing technology.

One of the demands of the learners in 21st-century skills is critical thinking in dealing with a real event. Critical thinking skills require learners to find solutions to problems that exist despite these facts and concepts. Learners must be accustomed to scrutinizing and implementing critical thinking to find the best solution to new problems so that they are able to make decisions with logical and scientific reasons.

In meeting these needs, a critical attitude is needed in students, especially during learning. To foster a critical attitude, it is necessary to use teaching materials that meet these needs. Multiple representation learning is able to find students' confusion in analyzing problems because it can help visualize the occurrence of a phenomenon in chemistry learning, including microscopic, macroscopic, and symbolic (Imaduddin & Haryani, 2019).

Representation skills need to be possessed by students in order to improve critical thinking skills. However, the problem that often occurs is that students cannot distinguish between macroscopic, microscopic, and symbolic. In addition, students are also not fully able to connect their understanding between macroscopic and microscopic, macroscopic and symbolic, microscopic and macroscopic, or microscopic and symbolic so that understanding of the material is sometimes only through memorization of material (Chandrasegaran et al., 2007). Students still do not fully have the ability to solve chemical problems because the teaching materials used tend to contain only two levels of multiple representation, namely macroscopic and symbolic, so that material that discusses particles or atomic arrangements is difficult for students to understand chemical concepts (Armiati & Pahriah, 2015).

In improving students' critical thinking skills, the multirepresentation approach can be integrated with the Problem-Based Learning (PBL) model. This is because learners can build their knowledge and look for correlations with problems encountered in everyday life by connecting each level of multiple representations. The PBL model can invite students to have the opportunity to gain hands-on experience in trying new things, for example, conducting simple experiments related to everyday life and then linking them to existing problems to find alternatives or solutions (Suswati, 2021). The experience and knowledge that learners have can improve their higher-level thinking, intellectual skills, and problem solving (Tyas et al., 2022).

PBL learning is centered on students where students have the opportunity to actively provide opinions, questions and rebuttals in solving exixting problems (Antara, 2022). the PBL model is able to

improve students' critical thinking skills because students collect data with their own strategies to support their critical thinking skills, then can provide arguments and conclude their findings until the stage of finding a solution so that this can support their critical thinking skills in chemistry (Fitriyah & Ghofur, 2021).

Therefore, referring to the above problems, this research will develop an innovative students' worksheet so that it is hoped that students will be able to connect macroscopic, microscopic, and symbolic, and be able to build their knowledge by actively expressing their opinions to find alternatives to the problems presented, especially in hydrocarbon mateerial which can be a solution to improve students' critical thinking skills in hydrocarbon topic.

METHODS

The development of multiple representation-containing students' worksheet integrated with Problem-Based Learning is a Research and Development (R&D) study with the research model used, namely 4-D developed by Thiagarajan (1974).

Data collection begins with direct observation of the field situation by visiting the destination school in pre-research activities. Observations were made in order to find out the needs of the school and develop appropriate teaching materials so that the research conducted was relevant to the problems in the school. During the observation activities, interviews were also conducted with chemistry teachers at SMA Negeri 12 Semarang to obtain an objective assessment in analyzing the needs of teaching materials as learning resources used.

The questionnaires used in this study include questionnaire sheets for material expert validation, media expert validation, and student responses to determine the feasibility, readability, product appearance, and effectiveness of product in this case, namely students' worksheet. Questionnaires are used to obtain the level of validity of the product developed from the assessment of expert validators, as well as students' responses to the use of multiple representation-containing students' worksheet integrated with Problem-Based Learning. The test method is a data collection technique in the form of a series of questions used to measure knowledge skills, abilities and talents (Riduwan, 2016). The test questions in this study were used to measure the achievement of critical thinking skills after the learning process using the developed students' worksheet. The questions consisted of 20 questions that were prepared based on the rids and indicators of critical thinking skills according to Ennis (2011).

Product validation data is presented in the form of a questionnaire sheet in the form of a table. Then analyzed with qualitative descriptive analysis techniques using a rating scale where raw data in the form of numbers are interpretation into qualitative terms (Sugiyono, 2015). Furthermore, the critical thinking skills test data analysis was carried out by calculating the validity of the items using the Biserial Point Correlation formula because the questions used were multiple choice with dichotomous scores and

students' total scores. The test instrument was also testes for reliability. Item reliability was analyzed using the Cronbach Alpha formulas. The reliability value generally refers to the value limit of 0,70 where if $r_{11} \geq 0,70$, then the test is declared to have high reliability, whereas if $r_{11} \leq 0,70$ then the test is considered not to have high reliability or is still classified as low (Sudijono, 2015).

Analysis of the effectiveness of the students' worksheet was carried out with the Wilcoxon Signed Rank test and Effect Size test. The Wilcoxon test was conducted to determine whether or not there was a significant difference between the pretest and posttest results after using the developed students' worksheet (Sugiyono, 2018). The Effect Size test is conducted on each critical thinking indicator Ennis (2011) to calculate the amount of effect or influence on nonparametric data after calculating the Wilcoxon test using the Rosenthal (1991) Effect Size formula. The Effect Size value has an influence after being treated if the value (r) is in the range of 0,30 – 1,00 with moderate to high effectiveness.

RESULT AND DISCUSSION

Result

The results of the study consisted of an analysis of the feasibility, effectiveness, and students' responses to the use of multiple representation-containing students' worksheet integrated with Problem-Based Learning.

Feasibility of Students' Worksheet

The preparation of students' worksheet has been adjusted to the systematics and structure of students' worksheet development according to Prastowo (2015) and modified slightly according to the needs of the study. The developed students' worksheet was analyzed to determine the feasibility assessed by expert validators using two validations, namely the validation of material experts and media experts, as well as readability through a student response questionnaire. The results of material expert validation are presented in Table 1 and media expert validation in Table 2.

Table 1. Material Expert Validation Analysis

No	Assessment Criteria	Score	Category
1	Accuracy of Coverage	33	
2	Quality of Content	53	
3	Language Quality	30	
4	PBL Model	52	Very Valid
5	Multiple Representation	34	
	Total Score	202	
	Validity Score (%)	88,59%	

Based on the results of Table 1, it can be said that the students' worksheet is valid with an average validity value on the material expert of 88,59% with a very valid category which indicates that the students' worksheet has met the minimum criteria of 55%.

Table 2. Media Expert Validation Analysis

No	Assessment Criteria	Score	Category
1	Techniques and Support Presentation	55	
2	Cover Design	42	
3	Layout	77	
4	Images and Illustrations	33	Very Valid
5	Colors	10	
	Total Score	217	
	Validity Score (%)	90,41%	

Based on the analysis in the table 2, it can be said that the students' worksheet is valid with an average validity value on media experts of 90,41% with a very category which indicates that the students' worksheet has met the minimum criteria of 55%.

The students' worksheet readability test was conducted to determine the responses of students to the students' worksheet developed. The readability aspect can be measured as part of the learner's response and an overview of the potential for practical students' worksheet to be used by students is obtained. The percentage results of the response questionnaire which are divided into several aspects and one of which is the readability aspect are presented in Table 3.

Table 3. Results of Readability and Small Scale Response

No	Assessment Criteria	Score	Average
1	Readability	424	88,33%
2	Appearance	351	87,75%
3	Content	329	82,25%
	Criteria		Very Good

Based on Table 3, it can be concluded that the results of the recapitulation of the response questionnaire on the readability aspect obtained a score of 424. This shows that the students' worksheet has a readability level of 88,33% with a very good category.

Effectiveness of Students' Worksheet

The test instruments that have been made are then tested for quantity by calculating the validity and reliability values. This is done to find out how much the assessment of questions in measuring the competence, knowledge, and critical thinking skills of students accurately. The reliability analysis of the test instrument can be seen in Table 4.

Table 4. reliability Analysis of Test Instrument

Reference Value	Cronbach Alpha Value	Conclusion
0,7	0,89	Reliable

Based on the results of Table 4, it is known that the reliability results on 20 items in this study obtained a Cronbach Alpha value of 0,89 which indicates that the test instrument has high reliability by

looking at the applicable standards, namely if the Cronbach Alpha value is 0,7, it is declared a good reliability indicator (reliable).

The students' worksheet effectiveness test was carried out by comparing data from the pretest and posttest results to determine the improvement of students' critical thinking skills before and after using the students' worksheet. The large-scale trial was conducted at SMA Negeri 12 Semarang to class XI-F.4 with 31 students. The pretest and posttest questions used consisted of 20 multiple choice questions oriented to critical thinking indicators according to Ennis (2011). The recapitulation of pretest-posttest results is presented in Table 5.

Table 5. Recapitulation of Pretest-Posttest Results

Class	Pretest Average	Posttest Average
XI-F.4	44,03	81,61

After obtaining pretest and posttest data, the Wilcoxon test can be carried out to determine the real difference between pretest and posttest values. Based on the Wilcoxon analysis, a value of 0,001 was obtained. This shows that there is a difference between the pretest and posttest values where the Asymp. Sig (2-tailed) of 0,001 < 0,05 which is the level of significance as the basis for decision making. The Wilcoxon test results are presented in Table 6.

Table 6. Wilcoxon Test Results

Test	N	Z	Asymp. Sig (2-tailed)
Pretest-Posttest	31	-4,880	0,001

After obtaining the results of the Wilcoxon test data, the Effect Size test was conducted to determine the significance of the resulting differences. Effect Size test was also conducted to determine the effectiveness of multiple representation-containing students' worksheet integrated with Problem-Based Learning. Based on the calculation results, the overall Effect Size result was 0,876. Based on the criteria according to Rosenthal (1991), the Effect Size value has an influence after treatment, if r is in the range of 0,30 – 1,00 so that the overall results show an increase in students' critical thinking skills after using students' worksheet with a high level of effectiveness.

Analysis of Critical Thinking Skills of Students

This analysis is to determine the effectiveness of students' worksheet on students' critical thinking skills on each critical thinking indicator used. The increase in critical thinking skills in each indicator using Effect Size is presented in Figure 1.

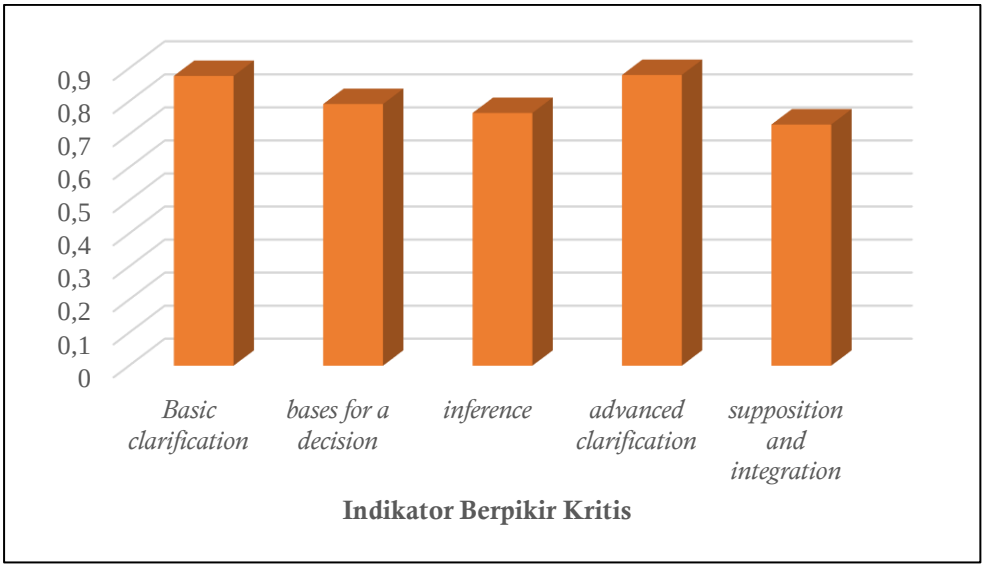

Figure 1. Results of Effect Size Analysis for each Critical Thinking Indicator

Based on the results of the analysis obtained, it is known that there is a significant increase in critical thinking skills in each indicator. This shows that the use of multiple representation-containing students' worksheets integrated with Problem-Based Learning is effective in improving students' critical thinking skills on all critical thinking indicators measured.

The next stage of analysis is the achievement of students' critical thinking through the average data of pretest and posttest scores. In addition, the test results were also interpreted into categories according to Riduwan (2015). The achievement of each indicator of critical thinking skills is presented in Figure 2.

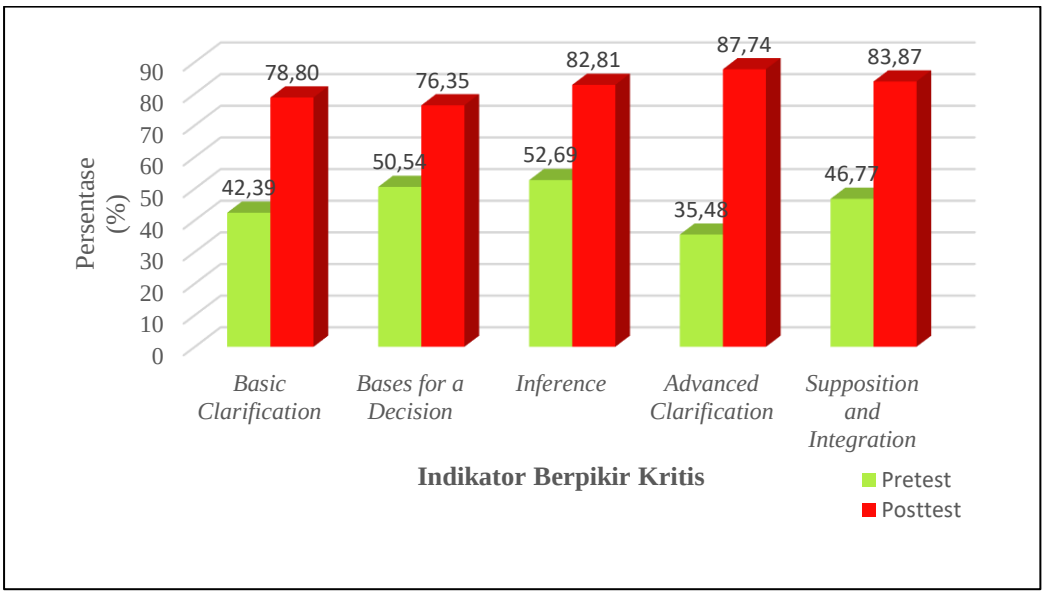

Figure 2. Achievement of Each Indicator of Critical Thinking Skills

Based on the analysis that has been done, it is known that the average value of the achievement of critical thinking indicators of students in the pretest is 45,58% with a moderate category, while the average value of the achievement of critical thinking indicators in the posttest is 81,92% with a very high category so it can be concluded that there was an increase in the posttest results and it can be said that the level of critical thinking skills of students is included in the high category.

Students' Response to Students' Worksheet

The response questionnaire was given by 31 students of class XI-F.4 SMA Negeri 12 Semarang. The response questionnaire was given to students after the learning process ended or after the use of multiple representation-containing students' worksheets integrated with Problem-Based Learning. The recapitulation of the students' response questionnaire to the students' worksheet is presented in Table 7.

Table 7. Recapitulation of Students' Response Results

No	Assessment Aspect	Score	Percentage (%)	Criteria
1	Readability	655	88,04	Very Good
2	Appearance	524	84,52	
3	Content	514	82,90	
	Average		85,33	

Based on the results of Table 7, it can be seen that overall, students after using multiple representation-containing students' worksheets integrated with Problem-Based Learning classified in very good criteria with an average value of 85,33%. This shows that students gave positive responses to the developed students' worksheet and were well received in every aspect of their assessment. This indicates that the use of students' worksheets in learning can increase the effectiveness of learning.

Discussion

This study was conducted with the aim of knowing the feasibility, effectiveness, and students' responses to multiple representation-containing students' worksheets integrated with Problem-Based Learning to improve students' critical thinking skills on the hydrocarbon topic.

Feasibility of Multiple Representation-Containing Students' Worksheet Integrated with Problem-Based Learning

The feasibility of the product in this study focuses on the validity and practicality of the developed students' worksheet. The validation of students' worksheets consists of the validation of material experts and media experts. The students' worksheet validation assessment involved three expert validators, including two Universitas Negeri Semarang lecturers and one SMA Negeri 12 Semarang chemistry teacher, by providing their assessment on the expert validation sheet provided. The validation value

according to the material expert is classified as very valid with a percentage of 88,59%. This shows that the students' worksheet developed is valid from the material aspect. While the validation value according to media experts is classified in the very valid category with a percentage of 90,41%. This shows that the students' worksheet is also valid from the media aspect.

Furthermore, a small-scale trial was conducted to determine the practicality of the developed students' worksheet. In the students' response questionnaire, one aspect of the assessment is the readability aspect. The readability aspect aims to evaluate the clarity of the language used in the students' worksheet, the sentence structure does not contain double meaning, and the sentence of the activity instructions is easy to understand. After conducting a small-scale trial, the response questionnaire was analyzed and obtained a readability result of 88,33% with very good criteria. This shows that the students' worksheet is suitable for use in learning chemistry hydrocarbon topic.

Effectiveness of Multiple Representation-Containing Students' Worksheet Integrated with Problem-Based Learning

The effectiveness of students' worksheet on improving students' critical thinking skills is determined based on how much the increase form the average pretest score to the average posttest score. The critical thinking skills test instrument consists of 20 multiple choice questions that have been adjusted to Ennis (2011) critical thinking indicators including Basic Clarification, Bases for a Decision, Inference, Advanced Clarification, and Supposition and Integration. Overall, to determine whether there is an increase in critical thinking skills or not, the Wilcoxon test can be carried out and obtained a result of 0,001 which indicates a significant difference in the pretest and posttest results. Then to find out how much influence the use of students' worksheet has on improving critical thinking skills can be done with the Effect Size test. In the results of the Effect Size analysis presented in Figure 1, it was found that the indicator on the highest critical thinking skills was the Advanced Clarification indicator with a result of 0,88 which was classified as a high effectiveness category. Based on the recapitulation of posttest results, it is known that students answer more correctly on items 15 and 18. This indicates that students are able to analyze the physical properties and chemical properties of alkane, alkenes, and alkyne compounds. This shows that leaning by using the macroscopic representation level, namely by linking material to everyday life, can build students' knowledge in understanding the concept of material and learning becomes more meaningful (Jayadiningrat & Ati, 2018).

Based on the data in Figure 1, the critical thinking indicator that obtained the lowest Effect Size result was Supposition and Integration, which obtained a result of 0,73. In item 20, students are asked to provide reasons and formulate combustion reactions that occur based on the illustrations presented. Students who answer incorrectly tend to be fooled by answer option D because the reason given seems to contain a negative meaning. This indicates that students are not yet fully capable of making logical

conjectures from the information presented. In addition, this indicator requires a multiple representation approach with all levels because the problem becomes difficult to imagine when there are no real pictures and compound structures of gasoline.

Based on Figure 2, the highest average increase in critical thinking skills is in the Inference indicator of 67,75%, while the lowest increase in critical thinking skills is in the Basic Clarification indicator of 60,60%. The results of the analysis using Effect Size used in analyzing the improvement of critical thinking skills measures the strength of the influence of using students' worksheet on improving students' critical thinking skills by taking into account the distribution of data and consistency of improvement. Meanwhile, the average analysis only calculates changes in pretest and posttest results without calculating the variation or distribution of data. Based on this, the Effect Size value on the Advanced Clarification indicator is higher because it describes a stronger and more evenly distributed influence on the entire sample, while the average analysis is more sensitive to changes in pretest and posttest results.

Students' Response of Multiple Representation-Containing Students' Worksheet Integrated with Problem-Based Learning

In the study, students' responses to multiple representation-containing students' worksheet integrated with Problem-Based Learning were carried out using a questionnaire sheet filled out by students. The recapitulation of the results of the students' response questionnaire presented in Table 7, shows that the average percentage is 85,33% with a very good category. Based on the data obtained, the aspect that received the highest score was the readability aspect with a percentage of 88,04% with very good criteria. This is because the language used in the students' worksheet does not contain double meanings and difficult terms, and each instruction uses sentences that are easy to understand. Then, the aspect with the lowest percentage is the content aspect with a value of 82,90% although the percentage is low, it is still classified as very good criteria. This is because students' worksheet in physical form makes it a little difficult for students to access anywhere because they have to bring students' worksheet first, making students less interested and need to bring stationery to answer questions.

The response of students after using the multiple representation-containing students' worksheet integrated with Problem-Based Learning is classified as very good or very interesting criteria. This is because the activities presented in the students' worksheet have followed the flow of the PBL model with the aim of improving students' critical thinking skills on hydrocarbon topic. In addition, the phenomenon associated with everyday life makes students interested in further solving problems and understanding the concept of the material. This is in line with research conducted by (Jawadiyah & Muchlis, 2021), that PBL students' worksheet is practically used in training critical thinking skills in chemistry learning with a percentage of students' response of 92,36% and classified as very good criteria.

CONCLUSION

Based on the findings of the study entitled "Development of a Multiple Representation-Containing Students' Worksheet Integrated with Problem-Based Learning to Improve Students' Critical Thinking Skills on the Hydrocarbon Topic," it can be concluded that the developed worksheet is feasible for use in classroom learning, as indicated by the results of expert validation and student readability assessments, both of which fall into the highly appropriate category. The implementation of the worksheet effectively enhanced students' critical thinking skills, as reflected in the significant increase in posttest scores categorized as very high. In addition, students responded very positively to the worksheet, indicating that the learning material is engaging, easy to understand, and supportive of their learning needs. Overall, the multiple representation–based worksheet integrated with Problem-Based Learning demonstrates strong potential as an instructional tool to foster critical thinking in hydrocarbon learning.

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