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Developing Problem-Based Learning Modules on Petroleum Materials in Chemistry Learning

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Abstract

The aim of this study is to investigate how to develop, validity, and practicality levels from the PBL-based module. The research is based on Research & Development (R&D) with a modified 4-D development model to 3-D covering define, design, and development stages. Data collection tools include observation, validation, worksheet, and questionnaires of students' responses to the chemistry modules. Based on the study results, it was identified that the modules developed to determine criteria eligibility, practicality, and response students of Problem-Based Learning on petroleum material. The material and media experts' validation tests showed 0.851 and 0.726 (valid), respectively. The average practically percentage of modules for students is 77.52% with very practical criteria. The development of PBL-based chemistry modules on chemistry and the application of petroleum is expected to help students in learning chemistry.

Keywords: define, design, development, petroleum, problem-based learning

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1. Introduction

Learning development is critical for channeling knowledge, values, and skills in the present and future. Digital media and technology can be utilized in the learning process. The learning process includes two critical important components; the teacher who serves as a facilitator, and the learner, who server as the primary object in the classroom (Nugraha, 2020). The use of teaching materials can contribute to transferring knowledge effective and efficient in the classroom (Minarni & Malik, 2019).

Teaching materials are a collection of learning facilities that include learning materials, methods, boundaries and evaluation methods that are designed in an interesting and systematic manner to achieve of learning objectives. The school must also create teaching materials, particularly for subject teachers. This is due to the fact that teaching material must adapt to school conditions and students' characteristics. According to the teaching material development guide, teaching materials must be developed in accordance with curriculum demands, target characteristics, and learning problem solving demands. The development of teaching materials must take into account the curriculum demands, which indicates that the teaching materials developed must be in accordance with the curriculum implemented at schools (Sanjaya, 2018).

Teaching materials themselves encompass several forms, which are printed, audio, visual, as well as interactive books. One form of visual teaching material in the process of conveying information with the implementation of drawing media in the form of comics (Asmaningrum et al., 2018). Teaching materials possess a role in corroborating the learning process, which is to enhance more interesting and motivating learning. Therefore, teaching materials are required which can enhance the learning process, hence, students in learning activities obtain good results (Salsabila & Nurjayadi, 2019). Recently, however some of the problems discovered by students incorporate students' lack of interest in reading textbooks, particularly chemistry printed books. It is because the printed book is based on the innovation of the learning material and the scope of the material is tremendously complicated. This has encouraged researchers to interested in researching the criteria eligibility and practicality of making PBL-based modules so that students can solve problems with examples of Papuan local wisdom.

In accordance with the results of observations, it was revealed that the school had implemented the Curriculum 2013 but for the application of the learning model in chemistry subjects only interspersed with the TPS (Think Pair and Share) model while still employing the lecture and discussion method. Furthermore, through observation questionnaires distributed to students 11th grade Natural Science, it was discovered that students still experience difficulty in learning and understanding the chemical materials contained in students' worksheet teaching materials and package books provided by the school. Moreover, students rarely perform questions on these teaching materials which can strengthen understanding and broaden their horizons associated with chemistry.

Thus, researchers are interested in developing a teaching material that can increase the enthusiasm for learning and understanding of students. Modules were developed as teaching materials for this study. Modules are self-contained teaching materials that are organized systematically and include clear learning objectives, learning activities, summaries, practice questions, and evaluations. A module can condition learning activities to be better planned and executed properly, independently, and completely, resulting in clear results (outputs) (Daryanto & Dwicahyono, 2014). The module developed in this study is in the form of a Problem Based Learning (PBL) based module in accordance with the Curriculum 2013 which requires to apply innovative learning models with a scientific approach. PBL-based modules are very good to utilize as they can make students learn by employing problems contextually, hence, students can be skilled and easy in solving problems and constructing student knowledge (Purnamasari et al., 2017).

This PBL-based module employs petroleum as a 11th grade Natural Science in chemical material. Petroleum is a chemical science that studies the occurrence of petroleum, it's composition, petroleum processing processes, gasoline, and the impact of fuel combustion. Some of these discussions must be understood and understandable rather than simply memorized, as they require a thorough understanding of the concept. Furthermore, petroleum is one of the subjects that students 11th grade Natural Science must understand (Sudarmo, 2004). It is what emphasizes the importance of making teaching materials in the form of PBL-based creating a chemistry module solving problems because they are equipped with examples of picture Papuan local wisdom and case studies to assist students in their learning process.

The results of research conducted by (Sari et al., 2022) discovered that a Problem Based Learning (PBL)-based chemistry module with a modified 4-D (3-D) development model indicates that the module is valid and practical. It is obtained with validity values from 3 validators by employing the Aiken index of 0.71 with valid criteria and an average percentage of practicality for all components of 84.5% with practical criteria. Moreover, the research performed by (Mellyzar et al., 2021) discovered that PBL-based modules with a 4-D development model are highly feasible and practical to implement in the learning process. It is demonstrated by the average score of material expert validators of 85.14% with very

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valid criteria and the average value of media expert validators of 72.57% with valid criteria and the average value of practicality for students of 91.47% with very practical criteria. Futhermore, the research performed by Assari, et al., 2023, showing the results of the feasibility assessment is 93.3% on the material aspect, 96.7% on the language aspect and 97.9% on the graphic aspect. The percentage of student was 88.5% in the small group test and 89.8% in the large group test, and 86.1% in the lecturer response test. Based on the result obtained, it can be concluded that the corporate edition flip pdf multirepresentation e-module about the acidpbase properties of organic compounds can be used as an additional learning resource.

The development of modules utilizing a Problem Based Learning learning model containing petroleum material distinguishes by illustrated examples used Papuan local wisdom and case studies to differentiate this research. This research similar, particularly on chemistry and applications of petroleum has been carried out, but containing Papuan local wisdom has never been conducted, particularly.

2. Research Method

This research was conducted during four months. This research employs a 4-D development model modified into 3-D, encompassing the defining stage, design and development (Thiagarajan et al., 1974; Borg, 2003; Darmadi, 2011). The Disseminate stage was not performed due to time and cost constraints.

The define stage encompasses five steps of analysis. The analysis carried out is front end analysis, student analysis, task analysis, concept analysis, and formulation of learning objectives. The data sources in this analysis were obtained from students 11th grade Natural Science and chemistry teachers. 4-D development model modivied into 3-D can be seen in Figure 1.

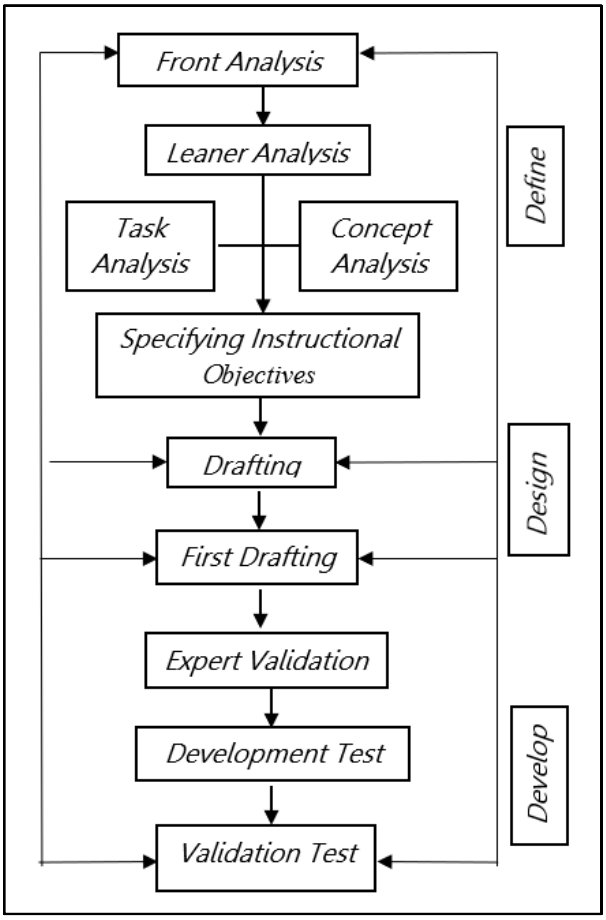

Figure 1. 4-D Development Model Modified into 3-D (Thiagarajan et al., 1974)

Furthermore, there are two stage in the design stage: selecting the module format and creating a module draft based on the results of the define stage analysis. It is performed to ensure that the modules created meet the needs of the students. The final stage is development. At this stage, the module's feasibility is examined by expert validation, which incorporates chemistry education lecturers and chemistry subject teachers as validator modules, as well as a module trial for determine students' reaction to the PBL-based chemistry modules developed.

This study utilized observation, interviews, validation sheets, student questionnaire sheets to collect data. The interview method was employed with the chemistry teacher, as well as observations of the chemistry learning process in the classroom, validation sheets to obtain data data based on validator

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assessments, and student questionnaire sheets, which include questionnaires for student needs conducted prior to the research and questionnaires for student responses to the modules developed.

The data analysis techniques conducted in this study are validity data analysis and practicality data analysis. Analysis of validity data employed Aiken's V formula which can be calculated as follows (Retnawati, 2016; Borg, 2003):

$$V = \Sigma \frac{s}{[n(c-1)]}$$

Information:
V = Content validity index
s = r – l_0
r = Scores from validators
l_0 = lowest scoring score
c = highest scoring score
n = Number of validators

After being tested, it will be analyzed with the validity criteria in Table 1.

Table 1. Eligibility Criteria for PBL Modules

Value Range V	Eligibility Level
0,80 – 1,00	Very Decent
0,60 – 0,80	Proper
0,40 – 0,60	Decent Enough
0,20 – 0,40	Less Viable
0,00 – 0,20	Very Less Feasible

(Hendryadi, 2017)

While the analysis of practicality data can be calculated using the formula:

$$p = \frac{number\ of\ score\ per\ item}{Maximum\ number\ of\ scores} \times 100\%$$

The criteria for analyzing student response questionnaires can be seen in Table 2.

Table 2. Learner Response Criteria

Percentage (%)	Criterion
80 – 100	Very Practical
66 – 79	Practical
55 – 65	Quite Practical
40 - 54	Less Practical
≥ 39	Very Less Practical

(Arikunto, 2009)

3. Result and Discussion

This research resultsed in a Problem-Based Learning-based chemistry module on petroleum material for 11th grade Natural Science that fulfilled the valid (feasible) criteria. The stages of development investigated in this study are as follows:

3.1. Define

The define stage (defining) is the initial stage performed in this study which encompasses 5 analyses, incorporating front end analysis, student analysis, and concept analysis, task analysis, concept analysis, and formulation of learning objectives. These analyses were conducted with direct observation and interviews with teachers and the distribution of initial questionnaires to students. The results of the front-end analysis obtained that the chemistry learning process has administered the Curriculum 2013, educators tend to perform the Think Pair and Share (TPS) cooperative learning model with lecture and discussion methods, teaching materials provided in the form of package books and LKS or worksheet which are not designed by the teacher himself, and there are no problem-solving-based module teaching materials.

According to student analysis, the teaching materials employed in schools in the form of worksheet and package books contained chemical materials, but the appearance of the teaching materials made it difficult for students to understand chemical materials. Furthermore, there is no problem-solving-based teaching material so problem-solving modules must be developed (Problem Based Learning). Furthermore, the task analysis is based on core competencies and basic competencies with petroleum materials. Which necessitates a thorough explanation and comprehension of the concept.

The defining phase is the development of learning that are customized to the material as well as the syllabus and Curriculum 2013. The objectives are as follow: a) explain the process of forming petroleum, the

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constituent components of petroleum, and the properties of petroleum, b) mention and explain petroleum separation techniques and the fractions produced, c) describe the utility of petroleum, d) identify the type of fuel oil (BBM) and octane number, and e) mention the impact of petroleum use and demonstrate how to overcome it. Concept map of petroleum can be seen in Figure 2.

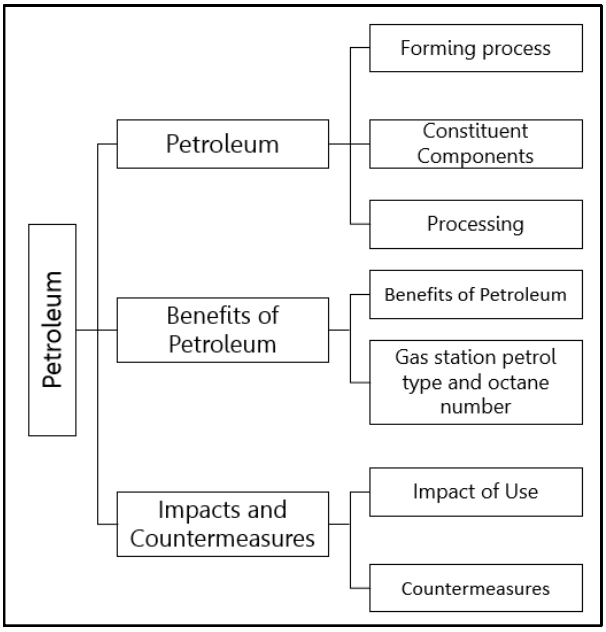

Figure 2. Concept Map of Petroleum

Petroleum is composed of complex mixtures of hydrocarbons, which are organic compounds consisting of hydrogen and carbon atoms. These hydrocarbons range in size from small molecules, such as methane, to large complex structures, such as asphalt. The specific composition of petroleum can vary depending on its source and the geological processes it has undergone (Wei, 2023).

Crude oil is the primary component of petroleum and serves as a vital source of energy worldwide. It is a thick, dark liquid that is typically extracted from underground reservoirs through drilling wells. Once extracted, crude oil undergoes a refining process to separate it into different fractions based on their boiling points. This refining process yields various petroleum products such as gasoline, diesel fuel, jet fuel, heating oil, and lubricants. Petroleum has numerous applications and is a key driver of the global economy. It is primarily used as a fuel source in transportation, powering cars, trucks, airplanes, and ships. It is also essential for electricity generation in many countries, either directly through the use of oil-fired power plants or indirectly through the production of natural gas, which is often associated with petroleum deposits (Carlson, 2023).

Crude oil (crude oil) has its constituent components because when processing occurs it will produce fractions in the form of gas, liquid and solid. The composition of petroleum is carbonate, sulfur compounds, nitrogen compounds, oxygen compounds, organometallic or inorganic.

The development of this module is related to petroleum material which contain Papuan local wisdom. Researchers are interested in providing Papuan local wisdom content in this module because Papuan has variety of biological natural wealth both teresterial and sea as endemic which has not been widely explored as petroleum or other oil material. These materials contain carbon compounds including the superior Papuan nutmeg plant in terms of content of aromatic carbon compounds such as safrole and myristicin which are used as medicine. In addition, Papuan nutmeg plant in Bitangur (*Calophyllum inophyllum*), which can be processed into oil through an extraction process. Papuan people use bitangur oil as an alternative to motor vehicle fuel (biodiesel), mace oil from mace trees as an oil producer. In addition, the endemic plant matoa (*Pometia pinnata*) has potential to absorb carbon that can help overcome the effects of burning petroleum. Then furthermore, Papuan is also a petroleum and mining producing area including an oil refinery at the Kasim, mining at PT Freeport and a gas producer at the Tangguh LNG.

It is important to note that the extraction, refining, and combustion of petroleum can have significant environmental impacts. The

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burning of petroleum products releases carbon dioxide and other greenhouse gases, contributing to climate change. Oil spills during transportation or drilling operations can harm ecosystems and marine life. The exploration and extraction of petroleum can also disrupt local communities and ecosystems (Wei, 2023).

3.2. Design

The Design stage (design) is performed based on the results of the analysis at the defining stage. The module designed is a Problem-Based Learning-based petroleum module and is designed. Furthermore, the module format phase must be really considered as it concerns two things, which are the consistency of the module content and the ease of reading the module (Prastowo, 2015). The module format is divided into three sections: before starting the material, while giving the material, and after giving the material. A title, foreword, table of contents, concept map, PBL stage, and introduction precede the presentation of the material. Following the presentation, the material comprises an evaluation, answer key, glossary, and bibliography. Covers module before (left) and after (right) are presented in Figure 3.

Figure 3. Petroleum Module Cover

At the time of delivery, the material included three learning activities. The first learning activity covered the formation of petroleum, petroleum constituent components, petroleum properties, and petroleum processing techniques. The second learning activity goes over petroleum fractions, their uses, and the different types of gasoline based on octane numbers. Meanwhile, the third learning activity examines the consequences of petroleum use and how to avoid them. Each learning activity involves a glimpse of interesting information and images about petroleum materials.

The creation of a module draft is another step of the design stage. The learning objectives to be achieved are used to draft modules. Furthermore, validation sheets are created and prepared to evaluate the feasibility level of the developed chemistry module, with each indicator in the validation, can be seen in Table 3.

Table 3. Validation Sheet Assessment Scale

Grading Scale	Score
Excellent	5
Good	4
Good Enough	3
Not Good Enough	2
Bad	1

(Borg, 2003)

3.3. Develop

After the module has been designed, the develop stage is conducted, which consists of an analysis of the module's validity and a module trial. The module validity analysis was assessed by two validators, chemistry education lecturers and chemistry subject teachers, by employing the Aiken index assisted by Microsoft Excel 2019. The module assessment employs an expert validation sheet that incorporates seven aspects: aspects of language use (3 indicators), aspects of chemical concepts (2 indicators), aspects of module format (5 indicators), aspects of independent learning resources (4 indicators), aspects of attractiveness (2 indicators), aspects of writing (3 indicators), and aspects of stages of Problem Based Learning (1 indicator).

The assessment by the validator obtained a validity score of 0.854 with significant valid criteria. Very valid criteria are obtained

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through Table 1 in which 0.854 is in the range of 0.80 to 1.00 (Hendryadi, 2017). When compared to relevant research by Natasari, (2020) who obtained a validity score of 0.82 with very valid criteria and Mellyzar et al., (2021) who obtained a material expert validity score of 0.851 with very valid criteria and media experts of 0.726 with valid criteria. It can be concluded that the valid criteria for modules with a value of ≥0.7 are suitable for use as teaching materials in the chemistry learning process. Hence, the validity score of this study is greater than that of relevant research. The improvement suggestion is limitted to the problem of typing words. After examining the feasibility level of the module, it is proceeded to the module trial step.

PBL based chemistry module validation on chemical materials. Based on the results of the module content validity test such as content eligibility, presentation with a value of 0.83 while language and graphics obtained a value of 1.00 indicating that the module is feasible to use with a value of ≥0.7 (Febriana et al., 2016). Naibaho & Suryani, (2023) have conducted PBL-based module research. The research results obtained a validity value of 0.86 with a valid category.

Based on the results of research conducted by Anom et al., (2018). The chemistry module is validated by three validator experts. Based on the assessment of the three validators, it said that with a value of 4.00 it was in a very valid category so that the chemistry module was very valid for use in the learning process.

Modules trials were conducted to determine student's reaction to the Problem Based Learning petroleum module. The experiment was performed on 22 students 11th grade Natural Science. The trial was conducted by describing learning with modules, holding group discussions with PBL-based case studies on modules, and then collecting data from student response questionnaires.

According to Table 4, the results of student responses obtained a percentage of practicality of 77.52%. It is in accordance with the research conducted by Lestari et al., (2020) who obtained a practicality score of 78% with practical criteria. Moreover, when compared with research by Sunaringtyas et which was higher than that of relevant studies, which received practicality score of 72.5%.

Table 4. Recap of Student Response Score Results

No.	Total aspects of the assessment	Percentage	Criteria
1	60	80	Very Practical
2	68	91	Very Practical
3	60	80	Very Practical
4	52	69.3	Practical
5	57	76	Practical
6	58	77.3	Practical
7	54	72	Practical
8	56	75	Practical
9	64	85	Very Practical
10	64	85	Very Practical
11	59	78.7	Practical
12	70	93.3	Very Practical
13	48	64	Practical
14	55	73.3	Practical
15	64	85.3	Very Practical
16	52	69.3	Practical
17	51	68	Practical
18	60	80	Very Practical
19	59	78.7	Practical
20	55	73	Practical
21	53	70.7	Practical
22	60	80	Very Practical
Average	**58.136**	**77.515**	**Practical**

Based on the results of research conducted by Wati et al., (2019) The results of validation by material experts average percentage of 87.7% with a very decent category. From the

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results of the media expert validation, an average percentage of 88% was obtained with a very feasible category, while from the assessment of students, an average percentage of 90.22% was obtained with a very feasible category. From the post-test, an average value of 89.11 was obtained. Therefore, the chemistry module is feasible to be used as a student learning resource.

Research conducted by Imanda et al. (2017) validated the quality of the module and received responses from teachers and students with a percentage of 84.65; 83.81%. Thus, it can be concluded that the chemistry module that has been developed is suitable for use in the learning process.

Naibaho & Suryani (2023) have conducted PBL-based module research. The results of the study obtained practicality test scores with an average percentage of 91% of students in the very practical category.

4. Conclusion

PBL-based chemistry modules on petroleum materials are created using a 4-D development model that has been modified into 3-D model, encompassing Define, Design, and Develop. There are five steps In the Define stage: front end analysis, student analysis, task analysis, concept analysis, and learning objectives formulation. Following that, the Design stage consists of two steps, selecting a format and creating a draft module. The final stage is Develop, which include two steps: expert evaluation and product trials. The Problem Based Learning (PBL)-based chemistry module on petroleum material was declared very valid or very feasible to be implemented as teaching material by two experts from chemistry education lecturers and chemistry subject teachers, with an average validity score of 0.854. According to the responses of grade XI science 1 students, the problem Based learning (PBL)-based chemistry module on practical chemistry and applications of petroleum is employed as teaching material, with a practicality percentage of 77.52%. This module has advantages so that students are interested in learning, such as showing examples of illustrations with Papuan local wisdom and case studies. Our research impacted the teachers expected to be able to increase knowledge students in understanding chemistry specifically on the applications of petroleum and can increase creativity.

The project-based worksheet includes six stages, which are analyzing the problem, designing the project, conducting research, evaluating the product, and finalizing and publishing the product. The worksheet is equipped with discourse that can direct students to carry out experiments. The project-based learning worksheet on making kefir whey paper soap as herbal soap is declared valid by obtaining to the r_{count} of 0.84 and was categorized as very suitable for use as a learning media in organic chemistry two courses.

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