HYDROGEN
JURNAL KEPENDIDIKAN KIMIA
https://e-journal.undikma.ac.id/index.php/hydrogen/index

July 2024. Vol 12 (No) 3
e-ISSN: 2656-3061
p-ISSN: 2338-6487
pp 497-511

Development Of Teaching Material To Support Merdeka Curriculum On Stoichiometry For Phase F

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Article History
Received : 27-05-2024
Revised : 25-06-2024
Published: 03-07-2024

Keywords: Teaching Material; Merdeka Curriculum; Stoichiometry Phase F.

Abstract
The merdeka curriculum is a new policy established by the Ministry of Education and Culture of the Republic of Indonesia as one of the steps in the design of learning recovery due to COVID-19. In maximizing learning recovery, innovative teaching tools are needed, one of which is by using the right teaching materials. The right teaching materials can facilitate teachers and students in the teaching and learning process. This study aims to develop teaching materials to support merdeka curriculum learning in SMA/MA phase F stoichiometry material. This research uses the Eduactional Design Research (EDR) method with the Plomp development model which consists of three stages, namely the preliminary research stage, the development or prototyping phase, and assessment phase. Data were collected using validity and practicality questionnaires. The subjects of this study were three chemistry lecturers, two chemistry teachers and nine students. The results showed that the validity test obtained a validity value of 88% which was declared a valid category. While the results of the teacher and student practicality test obtained a value of 91% and 93% which was declared a very practical category. Based on the results of the study, it was found that the development of teaching materials to support merdeka curriculum learning in SMA/MA phase F stoichiometry material was valid and practical.

How to Cite: Damiyanti, D., Mawardi, M., & Suryani, O. (2024). Development Of Teaching Material To Support Merdeka Curriculum On Stoichiometry For Phase F. *Hydrogen: Jurnal Kependidikan Kimia*, *12*(3), 497-510. doi:https://doi.org/10.33394/hjkk.v12i3.11687

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INTRODUCTION

Education is the implementation of the curriculum in the form of a learning process that can develop individual quality in achieving the standards of national education goals (Januarti et al., 2023). Education in Indonesia is currently experiencing a learning crisis after the Covid-19 pandemic. In response to the crisis, the government is trying to fix it by implementing a new curriculum, namely the merdeka curriculum (Amanda., 2023). The merdeka curriculum is one of the steps in the learning recovery design carried out by the Ministry of Education, Culture, Research, and Technology (Ariga, S., 2023). The merdeka Curriculum has several main characteristics that play an important role in improving the education system (Fadila et al., 2023). The implementation of an merdeka curriculum allows the educational environment to choose the optimal method to maximize learning (Nurhayati et al., 2022). One that can maximize learning to support merdeka curriculum learning is to provide innovative teaching tools.One of the teaching tools that can support learning is by using the right teaching materials (Utama et al., 2019).

Teaching materials are one of the important components to increase students knowledge and experience in the learning process (Fauzan et al., 2023). Teaching materials are systematically arranged based on learning outcomes in accordance with the applicable curriculum and are expected to increase student interest in independent learning (Magdalena et al., 2020). Independent learning aims to train students to have 4 competencies in the form of thinking components including critical thinking, problem solving, creating, and metacognition. The acting component includes communication, collaboration, digital literacy, technological literacy, flexibility and adaptability, initiative, and self-direction (Khairunnisak., 2023)(Dotimineli, A & Mawardi, M., 2021). Teaching materials should be equipped with multirepresentations. This is one way for educators to improve learning outcomes and student understanding (Andani & Yulian., 2018). One of the teaching materials that require multirepresentation is chemistry material.

Chemistry which is included in the natural sciences (IPA) is a collection of knowledge that is systematically arranged and generally limited in its application to natural phenomena (Mawardi, M & Fitriza, Z., 2019). The description of material in chemistry subjects requires a very good understanding, because it uses many concepts (Handri, S., & Mawardi, M., 2021). There are several concepts in chemistry that are abstract, making it difficult for students to understand the material (Kardena, H., & Mawardi, M. 2021). In understanding chemical concepts, multirepresentation of chemistry is needed, where there are three levels of chemical representation consisting of macroscopic, submicroscopic, and symbolic (Farida et al., 2018). Multirepresentation in teaching materials to support independent curriculum learning is expected to deepen students concept understanding in learning (Fauzan, F., et al, 2023).

One of the chemical materials contained in teaching materials to support merdeka curriculum learning is stoichiometry. Learning stoichiometry is very important because it is related to all aspects of chemistry and is the basis for learning various chemical materials such as thermochemistry, equilibrium, acid-base and others (Assma et al., 2018). Stoichiometry is one of the abstract chemical materials. According to (Zakiyah., 2018) stoichiometry material is still considered difficult for most high school students, because the material is quite complex to understand and involves a lot of mathematical concepts in solving calculation problems.

Based on the results of interviews conducted with teachers in several schools that implement the merdeka curriculum, namely SMAN 3 Padang, SMAN 8 Padang and SMA Pembangunan Laboratorium UNP, it was found that teachers from the three schools used However, from the observations of teachers at school, they still use the teacher-centered lecture method in the learning process, which is not in accordance with the demands of the independent curriculum which should provide student-centered learning. The teaching materials used in schools contain a lot of writing, material content that has not been detailed and the lack of multi-representation, especially in stoichiometry material. So that teaching materials are needed that contain material content and multirepresentation.

Research conducted by (Munitasari A., 2023) on the development of chemical e-books based on chemical representation of stoichiometry material, states that the e-books developed are valid. The use of textbooks can help teachers and students in learning, because it contains complete material (Arif, et al., 2023). This is in line with research proposed by (Rahmat et al., 2019), that the presence of multiple representations can improve students' critical thinking skills.

This study has several differences with previous studies. First, the teaching materials used are printed teaching materials. Second, the research was aimed at grade XI students. Third, the research method used the Borg and Gall development model. This research has novelty from previous research. The first novelty lies in the teaching materials developed in accordance with the merdeka curriculum. Second, the teaching materials developed are made by applying in everyday life so that they can increase students' understanding.

Development of teaching materials for the merdeka curriculum on stoichiometry material has never been done before. Therefore, research on the development of teaching materials for the merdeka curriculum will be carried out which will later be used as a textbook in supporting merdeka curriculum learning. Based on the background that has been described, research was conducted with the aim of developing teaching materials on stoichiometry material which is equipped with material content and multirepresentation which will later be used in supporting merdeka curriculum learning and is expected to help students achieve and understand learning material.

METHOD

The type of research used is development research or Educational Design Research (EDR) with the Plomp development model by Tjeerd Plomp (Plomp, T & Nieveen N., 2013) (Sitanggang et al., 2022). EDR is a systematic study to design, develop and evaluate educational interventions such as programs, teaching-learning strategies, learning materials, and the products developed can be used as solutions to complex problems in education (Mawardi, M & Nur, M. I., 2022). There are three stages in the development of Plomp, (1) preliminary research, (2) development or prototyping phase, and (3) assessment phase. Plomp's development stages can be seen in Figure 1. The research was conducted at SMA Negeri 3 Padang with research subjects namely 3 Chemistry Lecturers FMIPA UNP, 2 SMA Negeri 3 Padang teachers and 9 students of phase F SMA Negeri 3 Padang. The object of research is Teaching Materials to support Merdeka Curriculum Learning on Stoichiometry Material for Phase F SMA / MA.

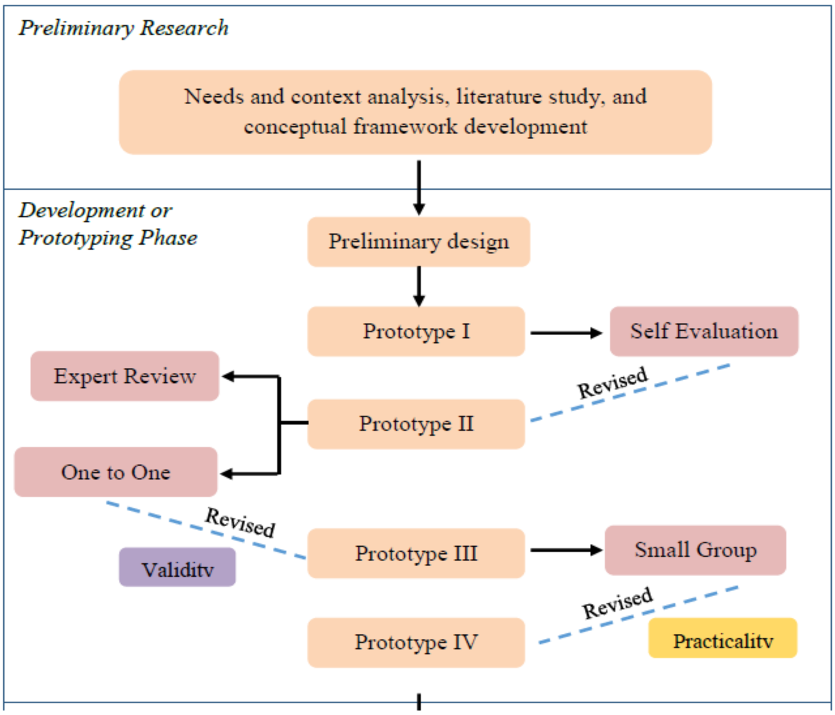


Figure 1. Research Desain

In the Preliminary Investigation Stage, a needs and context analysis, literature study, and conceptual framework development were conducted. Needs and context analysis was conducted by conducting interviews with teachers and students at school to get an overview of the basic problems faced and find solutions to the problems found. Literature study was conducted as a theoretical basis related to research development and finding solutions to existing problems through various sources. The development of a conceptual framework was made after the problems in the field had been found through needs and context analysis and literature studies conducted.

After conducting the preliminary research stage, the development or prototype stage is then carried out. During the prototype stage, formative evaluation will be carried out. At the prototype I stage, designing and compiling the content of the product material, then conducting a self-evaluation. Self-evaluation is carried out to review the completeness of the components in the developed teaching materials. If there are deficiencies, revisions will be made until prototype II is produced.

Prototype II is the result of improvements from prototype I, then expert review and one to one evaluation. Expert review carried out to provide assessments and suggestions for teaching materials that are being developed. This assessment was carried out by chemistry lecturers and chemistry teachers who acted as validators. Then, a one to one evaluation was conducted to find out the responses of students regarding the teaching materials being developed. Prototype III is the result of improvements from prototype II, Prototype III was carried out a small group test by teachers and students to assess the practicality of the teaching materials developed until prototype IV was produced which was an improvement of prototype III.

The data obtained was analyzed using the Aikens'V formula based on categorical judgments modified from Boslaugh and used for validity analysis. With categorical judgments, validators are given statements to convey their assessment of each statement. Where Aiken's V formula is as follows.

$$v = \frac{S}{n(c-1)}$$

$$s = r - I_o$$

Description:
S = The score assigned by the validator minus the lowest score of the category used
r = validator's preferred category score
Io = the lowest score in the scoring category
n = many validators
c = many categories chosen by the validator

Table 1. Aiken's V Scale Categories

Skala Aiken's V	**Deskripsi**
V ≥ 0.80	Valid
V < 0.80	Tidak Valid

Source: (Aiken, L. R., 1985)

While the data obtained from the practicality questionnaire, analyzed using the following formula:

$$NP = \frac{R}{SM} \times 100$$

Desccription:
NP = Percent value sought or expected
R = Raw score obtained by the student
SM = Ideal maximum score of the test concerned
100 = Fixed number

Table 2. Practicality Level Conversion

Nilai	Validitas
86% - 100%	Sangat praktis
76% - 85%	Praktis
60% - 75%	Cukup praktis
55% - 59%	Kurang praktis
≤ 54%	Tidak praktis

Source: (Purwanto., 2010)

RESULTS AND DISCUSSION

The results of the research on the development of teaching materials to support merdeka curriculum learning on stoichiometry material phase F SMA / MA with the type of educational design research (EDR) research using the Plomp model can be described as follows.

Preliminary Research

In the Initial Investigation Stage, a needs and context analysis, literature study, and development of a conceptual framework were conducted. The stages can be described as follows:

Needs and Context Analysis

The needs and context analysis was conducted by conducting interviews with teachers and students at SMAN 3 Padang, SMA N 8 Padang, and SMA Pembangunan Lab UNP. The purpose of conducting a needs and context analysis is to see a picture of the problems that occur in teachers and students in chemistry learning (Insani et al., 2022).

Based on the results of the interviews that have been conducted, it is concluded that the independent curriculum teaching materials available at school are not sufficient to improve students' understanding because there are still few variations of teaching materials and a lack of multirepresentation, especially in stoichiometry material. Multirepresentation in teaching materials can improve student understanding. This is in line with research proposed by (Rahmat et al, 2019), that the presence of multirepresentation can improve students' critical thinking skills. According to (Zakiyah et al, 2018) stoichiometry material is still considered difficult for most high school students, because the material is quite complex to understand and involves a lot of mathematical concepts in solving calculation problems. In the context analysis of stoichiometry that is deepest in the independent curriculum teaching materials in the form of the concept of moles, reaction equivalence, molecular formulas and empirical formulas, limiting reagents, and percent yield (Brady et al., 2012).

Literature Review

Literature review is carried out by collecting sources that are relevant to the research to be carried out (Syafei, S. & Mawardi, M., 2022). This stage is carried out by seeking information from various sources, books, journals and articles both national and international. Based on the literature study that has been carried out, the development of teaching materials on stoichiometry material is one of the steps in the design of learning recovery in the merdeka curriculum.

Teaching materials are one of the media used in assisting teachers and students in the teaching and learning process. Previous research relevant to this research is research conducted by (Sugria, et al., 2023) entitled "Development of teaching materials to support independent curriculum learning in phase F SMA / MA molecular form material". The results of the study state that the development of teaching materials is valid and practical for use by teachers and students in learning. Based on this, this teaching material is suitable for use to support the Merdeka curriculum. According to (Alamanda , et al., 2023) in order to make learning more efficient and effective and not deviate from the competencies to be achieved, the development of teaching materials is very helpful for teachers and students.

Conceptual Framework

The development of the conceptual framework resulted from the needs and context analysis stage and the literature study. The results of the analysis that has been carried out require merdeka curriculum chemistry learning resources, especially on stoichiometry material, so it is necessary to develop teaching materials to support merdeka curriculum learning on stoichiometry material. The development of the conceptual framework is made in the form of a scheme which can be seen in Figure 2.

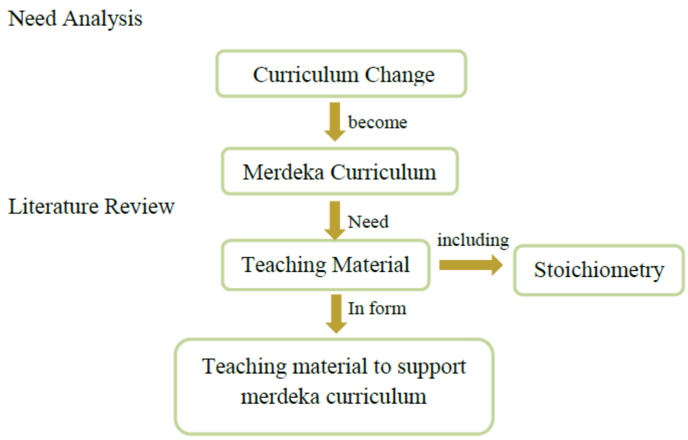


Figure 2. Conceptual Framework

Prototyping Phase

This development or prototype stage is carried out to produce products in the form of teaching materials to support merdeka curriculum learning on valid and practical stoichiometry material. The stages in the prototype are divided into four stages which can be described as follows:

Prototype I produces a product in the form of developing teaching materials to support merdeka curriculum learning on stoichiometry material. The components of the teaching materials have been adjusted to the merdeka curriculum standards. The components of the teaching materials consist of cover, preface, table of contents, instructions for using teaching materials, learning outcomes, learning objectives, concept maps, keywords, material content, sample questions and discussions, let's practice, activities, comprehension tests and final exercises which are equipped with Minimum Competition Assessment (AKM) assessment questions in accordance with the merdeka curriculum, summary, reflection, bibliography, glossary, index and answer key. Each stage of prototype development is carried out a formative evaluation which aims to revise the teaching materials developed several times so that no errors occur before being tested.

The prototype II stage results from the formative evaluation stage, namely self-evaluation which is carried out using the check list method, in the self-evaluation the researcher reviews the product if there are incomplete components, revisions will be made to complete the product components that have been developed. Based on the results of the self-evaluation conducted, the teaching materials that have been developed already have complete components and minimal errors.

Validity Result

The prototype III stage was obtained from the formative evaluation of expert review and one to one evaluation. The expert evaluation involved three chemistry lecturers from FMIPA UNP and two chemistry teachers from SMAN 3 Padang who acted as validators. The purpose of the expert assessment is to determine the validity level of the product related to content, presentation, language, and graphics. Expert judgment is carried out by filling out an evaluation questionnaire in the form of a content and construct validity questionnaire. The results of the content and construct validity analysis can be seen in Figure 3.

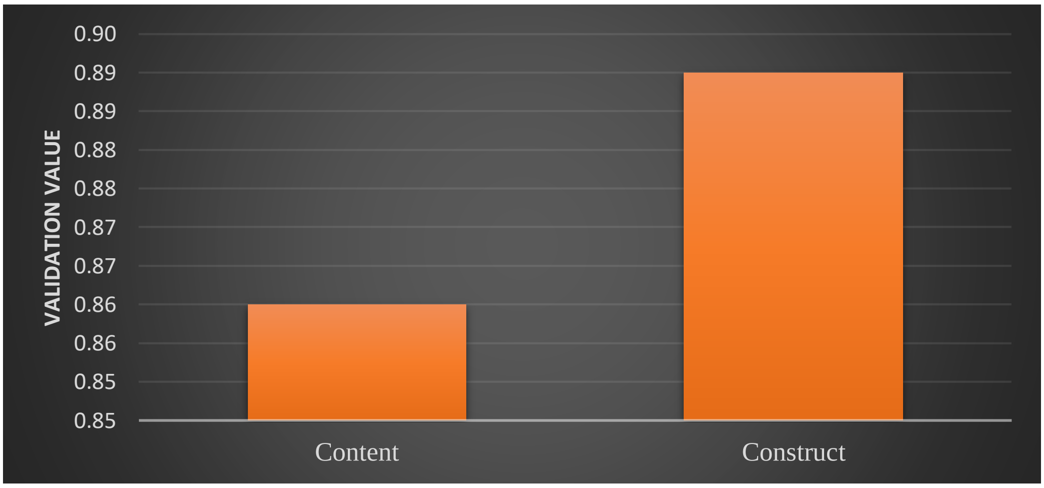


Figure 3. Validation Result

When conducting the validity test, the assessment carried out is in the form of content and construct assessment. Construct validity is validity related to the relationship of all components consistently with each other (Plomp & Nieveen, 2010). In the construct assessment there are four aspects of assessment which include, content eligibility components, presentation components, linguistic components, and graphical components (Depdiknas, 2008). The assessment aspect of the content validity test is the suitability of the content with the learning objectives. The results of data analysis on the content validity test assessment have an average validity value of 0.86 which is declared valid.

The results of the content feasibility test obtained a value of 0.99 with a valid category. According to (Cahyadi, 2019) teaching materials must be prepared based on specific learning objectives and to achieve these competencies the content in teaching materials usually comes from relevant textbooks. The results of the presentation component test obtained a value of 0.99 with a valid category. According to (Magdalena et al, 2020) teaching materials that are made systematically will make it easier for students in the learning process. The test results of the language component obtained a value of 0.99 with a valid category. This is in accordance with the National Education Department (2008) which states that to produce good teaching materials, it is necessary to evaluate the language component which consists of readability, clarity of information, conformity with good and correct Indonesian language rules and clear and concise language utilization. The test results of the graphic component obtained a value of 0.99 with a valid category. Based on the results of the assessment conducted by the validator, the average value of the Aikens V index is 0.88. Based on table 1, the validity questionnaire is included in the valid category. Thus the teaching materials developed were declared valid. After the teaching materials developed are valid, a one to one evaluation test is carried out.

One-to-one evaluation was conducted by interviewing three students of phase F of SMAN 3 Padang. The purpose of this stage is to get input and suggestions from students on the teaching materials developed. The results of the individual evaluation can be concluded that the teaching materials developed are interesting, the activities and exercises are varied in accordance with the demands of the merdeka curriculum, the language used is not complicated, and the teaching materials do not only contain writing but also presented images that support the explanation of the material so that it makes it easier for students to understand the material.

Practicality Result

Prototype IV resulted from a small group evaluation. This small group evaluation was conducted to nine students of XI MIPA 1 with different ability levels, namely low, medium, and high and two chemistry teachers at SMAN 3 Padang which aims to test the level of practicality of the products developed. The assessment carried out in this practicality test is based on aspects of ease, use, appearance, learning efficiency, and benefits in teaching materials. Learning begins by using the teaching materials developed. Students are also asked to fill out a practicality questionnaire which will later be used as a practicality value of teaching materials. In addition, the questionnaire was also given to chemistry teachers at SMAN 3 Padang. Based on Figure 7, the average percentage of practicality test results by students was 93%, while the average percentage of teacher practicality test results was 91%. Based on table 2, the practicality test is included in the very practical category.

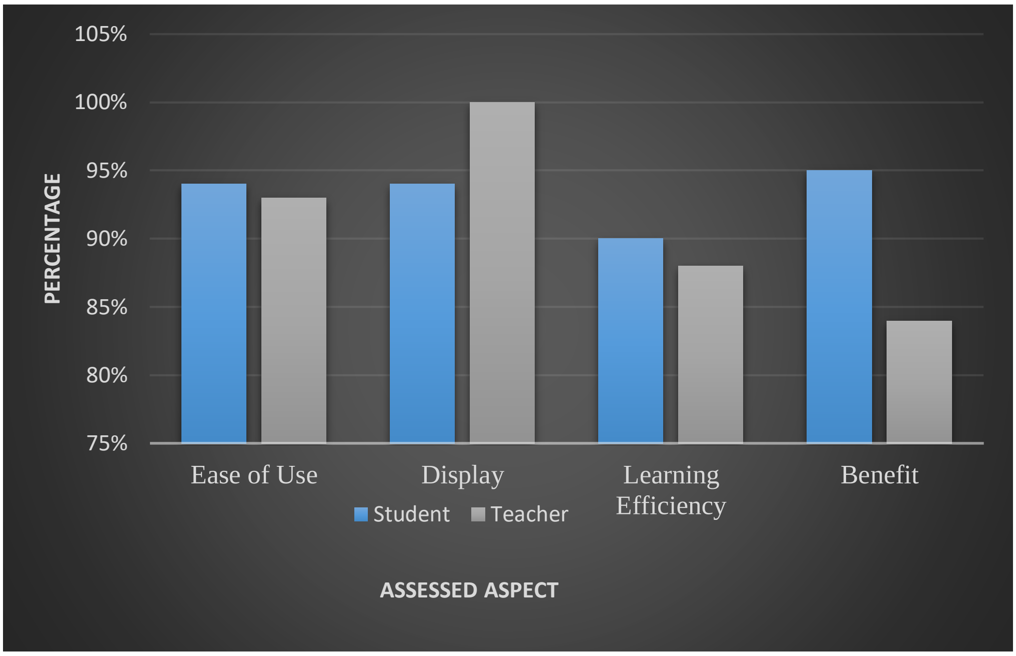
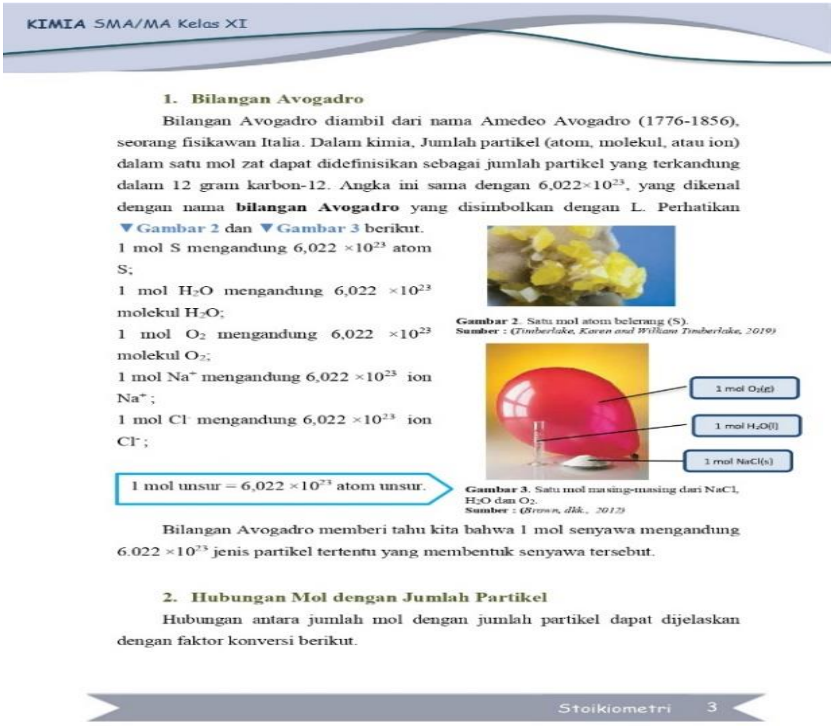


Figure 4. Practicality Result

The results of the practicality test by students and teachers show that the presentation of the material used is easy to understand. The content of the material provided is easy for students to understand. Practice questions can help students in understanding stoichiometry material. It can be concluded that the teaching materials developed are categorized as very practical. This is in line with research conducted by (Aasma, et al., 2018) and (Rahmi, C., 2023) suggesting that practical stoichiometry teaching materials are used in the learning process. This is in line with research (Elisa et al., 2020) that textbooks are included in the very practical category after the validity and practicality test stages.

Teaching materials equipped with multirepresentations both macroscopic, sub-microscopic or symbolic will facilitate students in the teaching and learning process. So that teaching materials with multirepresentations can maximize students to interact more with learning resources, so that students can learn independently in understanding chemical concepts. This is in line with (Sunyono et al., 2015; Supasorn, 2015; Permatasari et al., 2022; Supriadi et al., 2018; Wiyarsi et al., 2018) which states teaching materials with multirepresentations are effective for optimizing concept understanding in learning, building and improving students' mental models. The following is a display of teaching materials with multirepresentations that can be seen in Figure 5.



KIMIA SMA/MA Kelas XI

1. Bilangan Avogadro

Bilangan Avogadro diambil dari nama Amedeo Avogadro (1776-1856), seorang fisikawan Italia. Dalam kimia, Jumlah partikel (atom, molekul, atau ion) dalam satu mol zat dapat didefinisikan sebagai jumlah partikel yang terkandung dalam 12 gram karbon-12. Angka ini sama dengan $6{,}022\times10^{23}$, yang dikenal dengan nama **bilangan Avogadro** yang disimbolkan dengan L. Perhatikan ▼Gambar 2 dan ▼Gambar 3 berikut.

1 mol S mengandung $6{,}022 \times10^{23}$ atom S;
1 mol H_2O mengandung $6{,}022 \times10^{23}$ molekul H_2O;
1 mol O_2 mengandung $6{,}022 \times10^{23}$ molekul O_2;
1 mol Na^+ mengandung $6{,}022 \times10^{23}$ ion Na^+;
1 mol Cl^- mengandung $6{,}022 \times10^{23}$ ion Cl^-;

Gambar 2. Satu mol atom belerang (S). Sumber : (Timberlake, Karen and William Timberlake, 2019)

1 mol unsur = $6{,}022 \times10^{23}$ atom unsur.

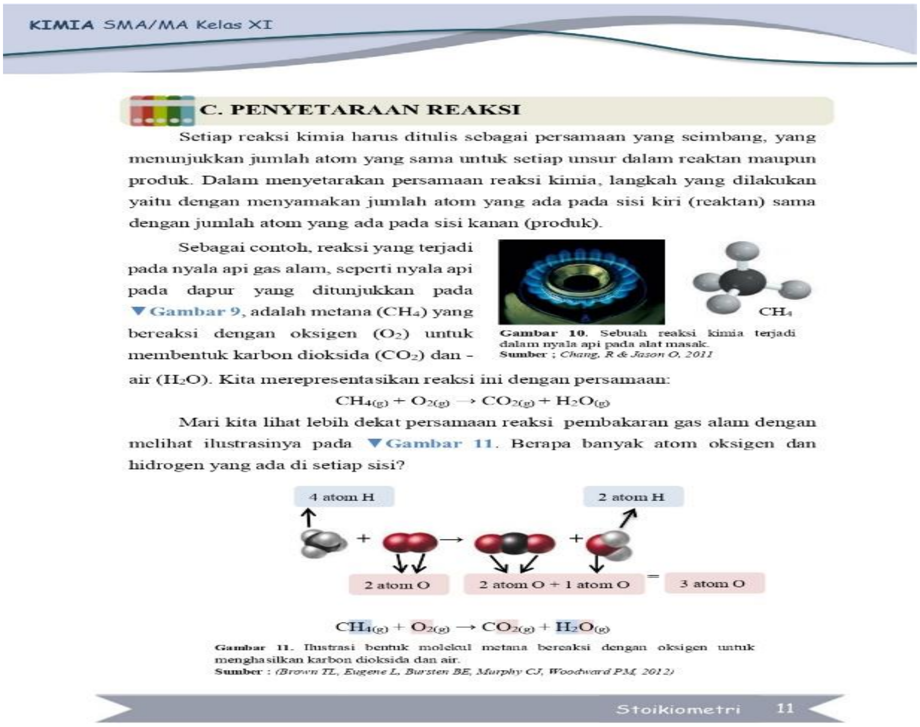
Gambar 3. Satu mol masing-masing dari NaCl, H_2O dan O_2. Sumber : (Brown, dkk., 2012)

Bilangan Avogadro memberi tahu kita bahwa 1 mol senyawa mengandung 6.022×10^{23} jenis partikel tertentu yang membentuk senyawa tersebut.

2. Hubungan Mol dengan Jumlah Partikel

Hubungan antara jumlah mol dengan jumlah partikel dapat dijelaskan dengan faktor konversi berikut.

Stoikiometri 3



KIMIA SMA/MA Kelas XI

C. PENYETARAAN REAKSI

Setiap reaksi kimia harus ditulis sebagai persamaan yang seimbang, yang menunjukkan jumlah atom yang sama untuk setiap unsur dalam reaktan maupun produk. Dalam menyetarakan persamaan reaksi kimia, langkah yang dilakukan yaitu dengan menyamakan jumlah atom yang ada pada sisi kiri (reaktan) sama dengan jumlah atom yang ada pada sisi kanan (produk).

Sebagai contoh, reaksi yang terjadi pada nyala api gas alam, seperti nyala api pada dapur yang ditunjukkan pada ▼Gambar 9, adalah metana (CH_4) yang bereaksi dengan oksigen (O_2) untuk membentuk karbon dioksida (CO_2) dan air (H_2O). Kita merepresentasikan reaksi ini dengan persamaan:

$$CH_{4(g)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(g)}$$

Gambar 10. Sebuah reaksi kimia terjadi dalam nyala api pada alat masak. Sumber ; Chang, R & Jason O, 2011

Mari kita lihat lebih dekat persamaan reaksi pembakaran gas alam dengan melihat ilustrasinya pada ▼Gambar 11. Berapa banyak atom oksigen dan hidrogen yang ada di setiap sisi?

$$CH_{4(g)} + O_{2(g)} \rightarrow CO_{2(g)} + H_2O_{(g)}$$

Gambar 11. Ilustrasi bentuk molekul metana bereaksi dengan oksigen untuk menghasilkan karbon dioksida dan air. Sumber : (Brown TL, Eugene L. Bursten BE, Murphy CJ, Woodward PM, 2012)

Stoikiometri 11

(a) (b)

Figure 5. Image material with 3 levels of chemical multirepresentation

In chemistry education, macroscopic and microscopic aspects play crucial roles in helping students understand complex concepts by providing different levels of observation and explanation (Tümay, 2023). The macroscopic level involves observable phenomena that can be seen, touched, and measured directly (Adams & Sonntag, 2022). Observing solids, liquids, and gases and their transitions (melting, boiling, condensation). Recording properties like temperature, pressure, volume, and mass. Noting color changes, precipitate formation, gas production, and energy changes (heat, light).

The microscopic level refers to the atomic and molecular world, which is not directly observable but can be understood through models and theoretical explanations (Amador-Bedolla & Olvera, 2009). Understanding protons, neutrons, electrons, and how they form atoms and ions. Learning about how atoms bond to form molecules, using models and diagrams to represent structures. Effective teaching materials incorporate both macroscopic and microscopic representations to bridge the gap between observable phenomena and underlying atomic and molecular theories (Gkitzia et al., 2020). Use visual aids to show how macroscopic observations (like color change) correspond to microscopic changes (like electron transfer) (Rahmawati et al., 2021). Allow students to manipulate variables and see both the macroscopic results and microscopic processes. Include tasks that require students to switch between macroscopic observations and microscopic explanations, enhancing their conceptual understanding (Hulyadi et al., 2023). By integrating both aspects, educators can provide a more comprehensive understanding of chemistry, enabling students to grasp the subject more effectively and build strong mental models.

Learning independence is one of the most important goals in the learning process. This is in line with the implementation of the independent curriculum which focuses on essential material, character development and student creativity. A rapidly developing modern society requires individuals who have the ability to think, act and communicate creatively (Wijaya, 2018). The creativity of students can be built one of them through learning independence.

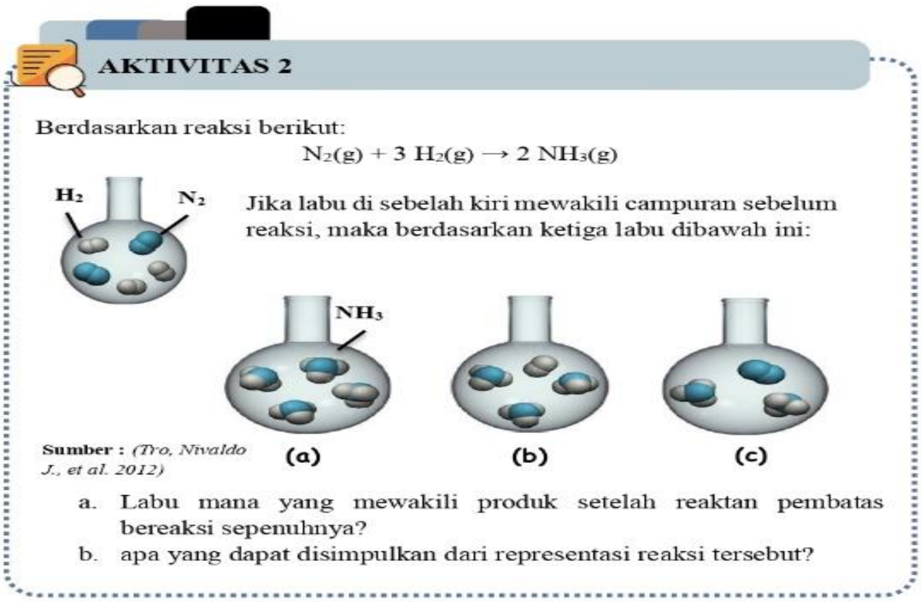


Figure 6. Activities in Teaching Materials

In addition to using multirepresentations, the inclusion of practice questions and challenging and diverse problem activities can also help students in understanding concepts. This is in line with Loewen's observation that incorporating challenging questions into the learning process can improve higher order thinking skills (HOTS), stimulate interest, and increase student motivation. One form of exercise that students must answer in the developed teaching materials can be seen in Figure 6, where students are required to answer practice questions and students are relied upon to understand the concept of limiting reagents. Based on the results of interviews conducted with students, it is known that reactants that have finished reacting are called limiting reactions. In the activity, students are guided to find out which of the three flasks presented represents the product after the limiting reactant has fully reacted. In this case students first find out which substance is the limiting reactant in the mixture of Nitrogen and Hydrogen. Almost all students answered Nitrogen. Based on the answers given by students, it is found that the images contained in teaching materials can make it easier for students to understand the material and answer questions correctly. Thus, the use of teaching materials is not an obstacle for students in carrying out learning independently.

CONCLUSION

The research shows that the merdeka curriculum teaching materials on phase F stoichiometry material that have been tested for validity obtained an average score of 88% which is categorized as valid and the results of the practicality test on teachers obtained an average score of 91% and on students of 93% which is categorized as very practical. Based on the research results, it is found that the development of merdeka curriculum teaching materials on stoichiometry is valid and practical.

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