Development of Teaching Materials to Support Learning of the Merdeka Curriculum on Chemical Equilibrium

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Abstract: Teaching materials are an essential part of independent curriculum learning. This study aims to determine valid and practical teaching materials on chemical equilibrium material that can support learning the independent curriculum phase F SMA / MA. The research used the Education Design Research type of research with the Plomp development model. The research includes development stages up to prototyping and testing in small groups. The instruments used were a validity questionnaire and a practicality questionnaire. Validity was assessed using the Aikens ' V formula modified by Purwanto to assess practicality Purwanto. The results showed that the validity test obtained 0.86 with a valid category. The results of the practicality test for teacher responses were obtained at 95% with an efficient category, and for student responses, obtained at 95% with an efficient category. These results state that the teaching materials created and developed are valid and practical. Then, the results showed that the multilevel representation approach emphasizes mastery at the macroscopic, submicroscopic, and symbolic levels. Mental models can be used to describe these three levels. A good mental model can help students relate scientific concepts to their thinking.

Abstrak: Bahan ajar adalah bagian penting yang dapat membantu pembelajaran kurikulum merdeka. Tujuan penelitian ini untuk menentukan bahan ajar valid dan praktis pada materi kesetimbangan kimia yang dapat menunjang pembelajaran kurikulum merdeka fase F SMA/MA. Penelitian menggunakan jenis penelitian *Education Design Research* dengan model pengembangan Plomp. Penelitian mencakup tahapan pengembangan hingga pembuatan prototipe dan pengujian pada kelompok kecil. Instrumen yang digunakan yaitu angket validitas dan angket praktikalitas. Validitas dinilai dengan rumus Aikens'V, dan praktikalitas dinilai dengan rumus yang dimodifikasi oleh purwanto. Hasil penelitian menunjukan untuk uji validitas didapatkan 0,86 dengan kategori valid. Dan hasil uji praktikalitas untuk respon guru didapatkan sebesar 95% dengan kategori sangat praktis serta untuk respon peserta didik didapatkan sebesar 95% dengan kategori sangat praktis. Hasil ini menyatakan bahan ajar yang dibuat dan dikembangkan telah valid dan praktis digunakan. Kemudian hasil penelitian menunjukkan bahwa pendekatan representasi multilevel menekankan penguasaan pada tingkat makroskopik, submikroskopik, dan simbolik. Model mental dapat digunakan untuk menggambarkan ketiga level tersebut. Model mental yang baik dapat membantu siswa mengaitkan konsep ilmiah dengan cara mereka berpikir.

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A. Introduction

The Merdeka curriculum is a new curriculum where varied intracurricular learning gives students sufficient time to learn and understand their abilities (Kemdikbud, 2022). Teachers are free to select their teaching resources in this autonomous curriculum to meet the needs and desires of students (Barlian & Solekah, 2022). The pedagogical tool under consideration takes the shape of instructional materials (Arisanti, 2022). Teaching materials are one of the teaching tools that help implement the Merdeka curriculum. Creating chemistry teaching resources to supplement the primary textbook the Ministry of Culture and Education supplies is crucial when implementing an autonomous curriculum. This is to earlier studies carried out by Fauzan et al (2023) and Mawardi & Fani (2022), which said that there are still few resources for learning available as educational resources that use the Merdeka curriculum. This limitation can hinder the achievement of predetermined learning outcomes and potentially reduce student learning outcomes.

Teaching materials are any resources that can help the instructor or teacher carry out the learning process in the classroom. Teaching materials consist of written or unwritten materials such as text, information, or structured materials that demonstrate the skills that students will learn. Examples of written teaching materials include chapter books (textbooks), models or markets, LKS, interactive teaching materials, modules, audio teaching materials, and others. Every resource has content that has been thoughtfully organized to meet learning objectives while adhering to teaching standards. In addition to content, instructional materials include activities, summaries, and discussion topics to aid students' learning (Purwati & Erawati, 2021). Chemical equilibrium material is among the resources created for teaching

Chemical equilibrium impacts chemistry learning topics and is one of the most important concepts in chemistry because it is interrelated (Kajornklin et al., 2022). Chemical equilibrium is essential because it is one of the basic concepts for learning further chemical materials. However, it is among the chemical substances considered challenging and intricate (Siregar & Mawardi, 2022). Dynamic equilibrium, equilibrium constant, and equilibrium shift are sub-materials of chemical equilibrium that are considered difficult (Andriani et al., 2021).

Based on observations that researchers have made at SMA Negeri 3 Padang, SMA Negeri 8 Padang, and SMA Pembangunan using questionnaire distribution techniques to students and Using teacher interviewing methodologies, it was discovered that 72.26% of teachers believed that equilibrium material was difficult for pupils to understand. Students think that many factors make chemical equilibrium material difficult, namely abstract material concepts, difficulties in understanding terms that arise because students not only memorize the meaning of terms in chemical equations but need to understand them fully, and difficulties in calculations (Seliwati, 2017). Only some instructional materials support the autonomous curriculum as a learning tool. Research supports this assertion (Angga et al., 2022) that only teacher guides are comprehensive, and there needs to be more instructional materials for pupils following an autonomous curriculum. An additional

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viewpoint is consistent with (Suryani et al., 2023) because there are still relatively few resources for instructional materials available to meet the requirements of the autonomous curriculum. The information offered in the dispersed autonomous curricular teaching materials needs to be well-detailed, and the presentation of various representations needs to be improved.

Chemical multi-representation is the formation of concepts that can apply three types of representations. To create three levels of learning: symbolic, microscopic, and sub-microscopic, or molecular representations. The chemistry learning process uses multi-representation, which helps communicate chemical ideas. These representations are essential for students to comprehend chemistry (Fitriza et al., 2019). The depiction of the three levels can be achieved by developing mental models. Developing an excellent mental model can help students connect scientific concepts to their thinking to overcome misconceptions in learning. The connection between the three levels in this teaching material is expected to build a correct student mental model to understand chemical equilibrium material (Fitriza et al., 2019). Therefore, teaching materials that contain multiple chemical representations are needed to support students' mental models that can support Merdeka's curriculum learning. Students' mental models develop better after using teaching materials. This relates to teaching chemistry by employing instructional materials to increase students' comprehension of the subjects covered in the lesson (Mardatilla et al., 2023)

The teaching material is appropriate for supporting curriculum Merdeka learning and is based on the theory and challenges described. This will assist students in comprehending and achieving the concept of the material in learning. This is consistent with a study conducted by Alamanda et al (2023) and Januarita et al (2023), which state that the creation of instructional materials is very beneficial for teachers and students to make learning more effective and efficient while staying true to the desired competencies. In addition, teaching materials that contain multiple chemical representations are needed so that students' mental models increase and support Merdeka's curriculum learning. Research on Merdeka curriculum teaching materials on chemical equilibrium material with mental models using multiple chemical representations has never been developed. One way is to create teaching materials containing material content referenced from textbooks and equipped with complete multi-representations. Therefore, researchers are interested in developing teaching materials to support independent curriculum learning on chemical equilibrium material with continuous material content and equipped with various multi-representations that will be used as teaching books to support independent curriculum learning. This research aims to develop teaching materials on chemical equilibrium material equipped with material content and multi-representation, which will later be used as a textbook to support independent curriculum learning.

B. Method

Development Research Design, referred to as Education Design Research (EDR), is the study carried out. The Plomp development model was used as the development model

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in this study. This development model has three stages: the initial investigation stage, the prototype development stage, and the assessment stage (Plomp & Nieveen, 2013; Mawardi & Fani, 2022).

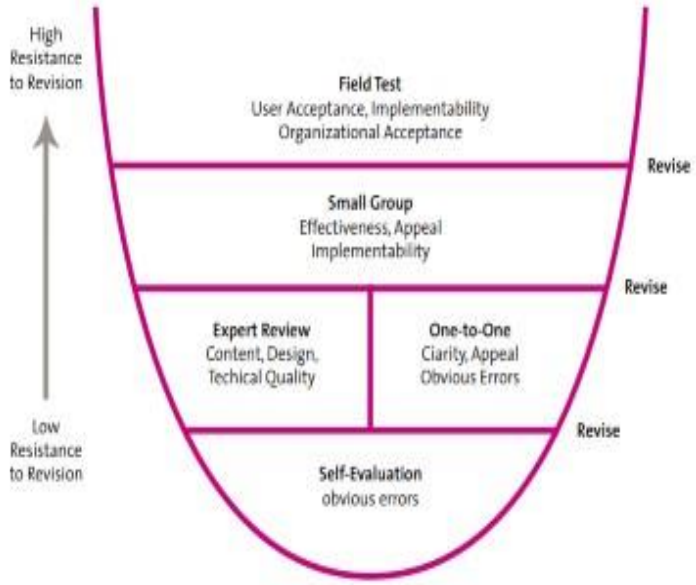

Figure 1. Phases of Formative Assessment Studies

This study was conducted on three UNP chemistry lecturers and two SMA Negeri 8 Padang chemistry teachers who will determine the validity value, which will be carried out by five validators using a research instrument in the form of a validation questionnaire. Two chemistry teachers and nine phase F students from SMA Negeri 8 Padang will determine the practicality using a research instrument in the form of a practicality questionnaire sheet. The students were classified based on different student abilities (high, medium, and low). In addition, this research was conducted to create instructional materials that complement or enhance learning in the Phase F SMA / MA Merdeka curriculum of chemical equilibrium material. The data analysis technique uses validity, which will be analyzed using the formula (Aiken, 1985), and the practicality obtained is examined using a modified version of the (Purwanto, 2010).

A needs and context analysis, as well as a conceptual framework study of the instructional materials, were established in the first phase. This stage aims to paint a picture of the issues that arise while students and teachers are learning chemistry (Insani et al., 2022). At this stage, preliminary research is conducted. First, it starts with a needs analysis, namely an interview technique related to the teacher's response to the current user situation and how to get the expected situation. This activity was carried out by three chemistry teachers from various education schools. Next is the context analysis, which is an analysis to see the scope of the problem. In this activity, an analysis of teaching materials and content

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in schools and curriculum is carried out by analyzing CP, derived into TP (Novia et al., 2023). Following that, references and sources pertinent to the research are analyzed in the literature study stage, where this stage is carried out. These sources and references include books, articles, theses, and journals. The final stage is to create a conceptual framework in response to issues recognized and connected to current ideas (Ninda & Mawardi, 2022).

The second step is to create instructional resources to enhance learning in the autonomous curriculum on chemical equilibrium subjects. The stages that will be carried out in the prototype phase are prototype I, developing the results of the design of teaching materials. Prototype I is evaluated by self-evaluation and revision of the results of prototype I into prototype II. Prototype II will be evaluated through expert assessment to assess the importance of individual judgment, practicality, and validity. A validation questionnaire is used in this expert assessment as a validation test instrument, namely content validation and construct validation. However, in general, there are several components in the assessment aspects, namely the linguistic, content, graphic, and presentation components (Depdiknas, 2008). Prototype III will be created using the updated findings of the expert assessment and individual evaluation. Students will take a small-group test (Prototype III) to determine whether the instructional materials are helpful. Then, the revision of prototype III will become a prototype IV teaching material product that has been said to be valid and practical.

This research will employ instructional resources to facilitate learning within the chemical equilibrium material phase F SMA / MA Merdeka curriculum. The validity data results were obtained using the Aikens 'V formula.

$$V = \frac{\sum s}{n(c-1)}$$

Description:

V = Index of validity assessment
s = Score r-I_o
r = The Score given by the validator
I_o = The validity assessment lowest Score (I_o=1)
c = The validity assessment's highest Score (c=5)
n = Quantity of validators

Table 1. Validity Category

Skala *Aiken's V*	Category
$V < 0{,}80$	Invalid
$V \geq 0{,}80$	Valid

Source: (Aiken, 1985)

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Data on practicality derived from the formula:

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

Description:
NP = The percentage amount obtained or desired
R = Number of scores attained
SM = The Sum of the highest scores obtained

Table 2. Practicality Level Category

Score	Practicality
86%-100%	Highly Practical
76%-85%	Quite Practical
60%-75%	Practical
55%-59%	Less Practical
≤54%	Not Practical

Source: (Purwanto, 2010)

C. Result and Discussion

Result

The study's outputs include instructional resources that complement Merdeka's curriculum instruction on chemical equilibrium phase F SMA/MA content, which has proven valid and practical. The study, which has been conducted, uses the Plomp model, which comprises multiple stages and is explained below.

Preliminary Research

Needs analysis

This research's first phase involved creating a conceptual framework, assessing pertinent literature, analyzing needs and context, and identifying educational issues in the field (Ismail & Mawardi., 2021). At the needs analysis stage, an initial study was conducted to identify problems and needs for the teaching materials developed. Schools will prepare teaching materials to address various issues that come up in schools. The conclusions from the observations and interviews with the three chemistry instructors from the three high schools, SMA Negeri 3 Padang, SMA Negeri 8 Padang, and SMA Pembangunan according to the interview's findings, students struggle to comprehend the concepts of chemical equilibrium. Abstract material conceptions are among the things that lead students to believe that chemical equilibrium is a challenging subject, and they need help understanding concepts such as equilibrium equations and dynamic equilibrium.

Furthermore, a lack of teaching materials misrepresented chemical equilibrium material (Mawardi & Fitriza, 2019). Thus, multi-representation is needed to help students find concepts and build mental models for the better. Incorrect mental models in chemical equilibrium material result in not understanding further chemical concepts (Fitriza et al.,

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2019). Therefore, a way is needed so that misconceptions in chemical equilibrium material do not occur so that the correct mental model is obtained in this material. Then, there are still few teaching resources available in schools that use the autonomous curriculum for chemical equilibrium content.

Context Analysis

The context analysis step comes after the needs analysis. This context analysis step examines the substance of the curriculum and the teaching materials. Each of the three schools has implemented its curriculum based on the findings from observations and interviews. However, The Merdeka curriculum has yet to be implemented to its full potential. In this case, curriculum analysis will be carried out to reduce learning outcomes to learning objectives. The expected learning outcomes for chemical equilibrium material are that students can apply mathematical operations in chemical calculations. Then, it can understand and explain the equilibrium concept in chemical reactions (Kemdikbud, 2022). The chemical equilibrium material in the Merdeka curriculum textbook is the concept of chemical equilibrium, equilibrium constant, using equilibrium constant in calculations, equilibrium shifts, and chemical equilibrium in the industrial world.

Literature Study

The literature study aims to integrate the dynamics of issues teachers and students have when learning the autonomous curriculum to provide solutions and answers by analyzing scientific articles in various journals. It is known that these problems need to be designed as a product, specifically the creation of instructional resources to enhance learning in the chemical equilibrium content Merdeka curriculum in phase F SMA / MA utilizing the Plomp model of development and being knowledgeable about its degree of validity and practicality.

Conceptual Framework

This stage is used to identify problems arising from the previous stages, namely the needs and context analysis, and connect them with literature studies. This framework can summarize the dynamics of the problems found in schools and provide solutions to overcome them (Syafei & Mawardi, 2022). The conceptual framework is displayed in Figure 2.

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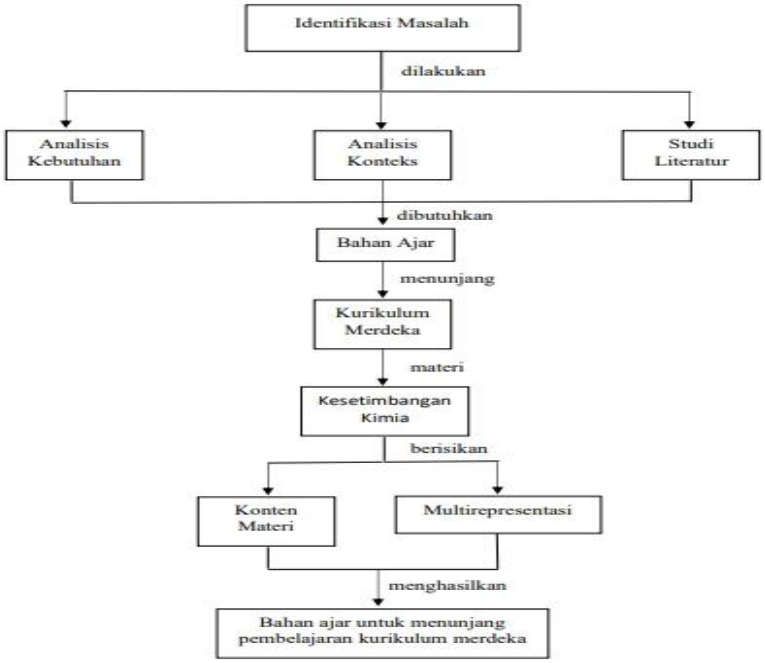

Figure 2. Conceptual Framework

Prototyping Phase

Prototype I

Design products as instructional materials for chemical equilibrium materials at the prototype I stage. The components of instructional materials were taken into consideration when designing this product. Teach ng materials are formatted with cover components, a preface, a table of contents, usage guidelines, CP and TP, concept maps, exercises, practice questions and conversations, comprehension assessments, end-of-material tasks, projects (practicum), summaries, reflections, bibliographies, glossaries, indexes, and answer keys incorporated into the presentation of the material (Fadila et al., 2023). The following is the result of prototype I in Figure 3.

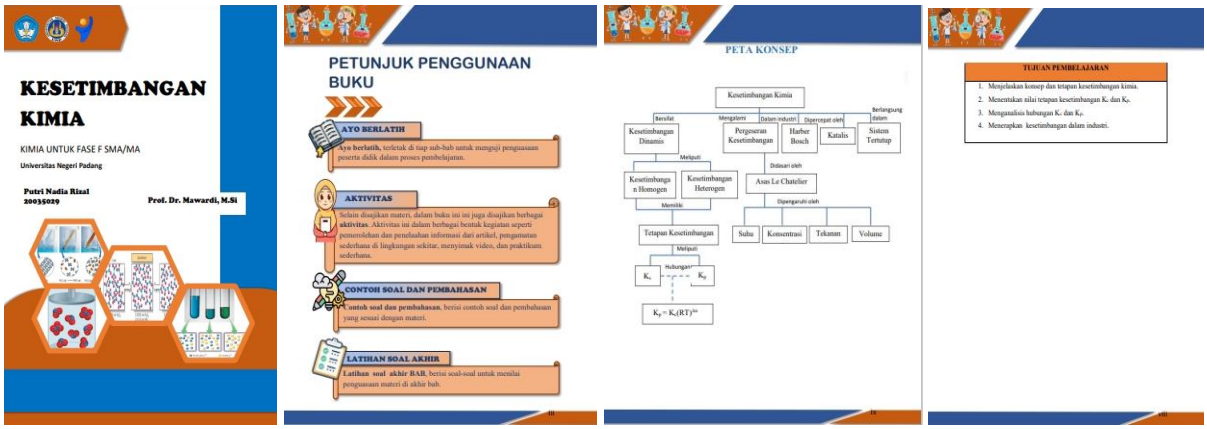

Figure 3. Coverage of Instructional Resources, Usage Guidelines, and Learning Objectives

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Prototype II

The prototype II stage contains the revision and evaluation stages carried out on prototype I. This stage includes a form of self-evaluation. Use a checklist for self-evaluation to ensure that all parts are present and that the content in the created instructional materials is aligned (Camelia & Mawardi, 2023). Then, the evaluation results from the prototype show that the instructional resources are comprehensive and in compliance with the components, and there are no more errors in the teaching materials (Firdaus et al., 2023).

Prototype III

Expert Review

An expert review, namely an expert assessment, is conducted by five validators. In this, validity will be assessed using Aiken's V formula. Each validator is asked to assess the advantages and disadvantages of the product so that they can be known to determine its feasibility. The validators used a construct validity and content validity questionnaire to evaluate. Figure 8 displays the findings from the validity data analysis. Valid teaching materials are obtained after making revisions according to the experts' suggestions for the components of teaching materials. The following is the display after the revision.

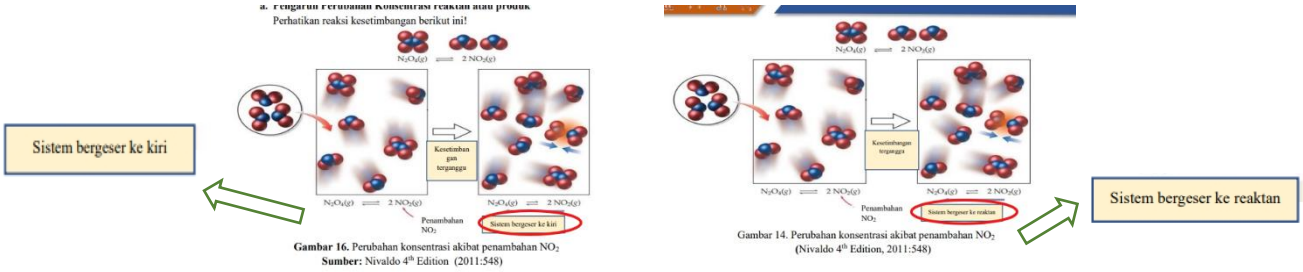
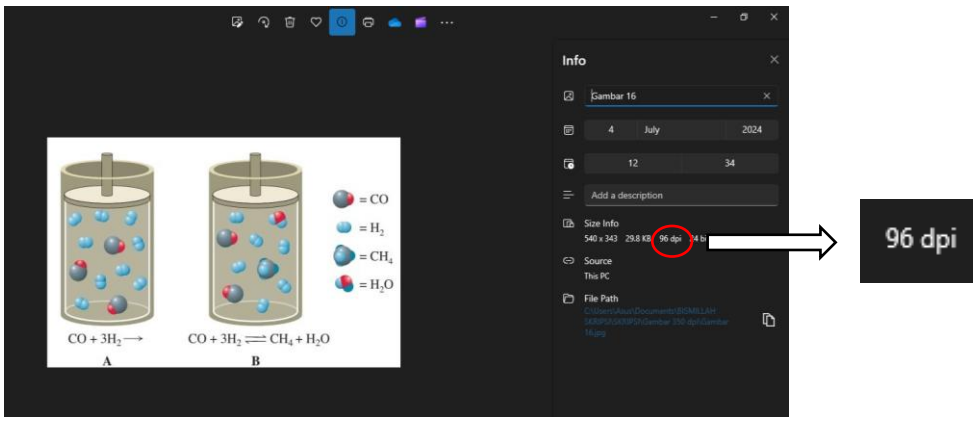


Figure 4. (a) Revision before Replacing the Word "Reactant" and (b) Revision after Replacing the Word "Reactant" after Revision.



(a)

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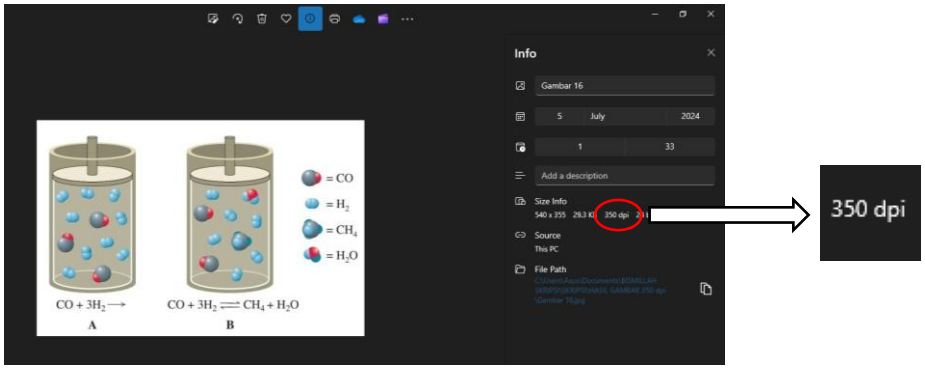
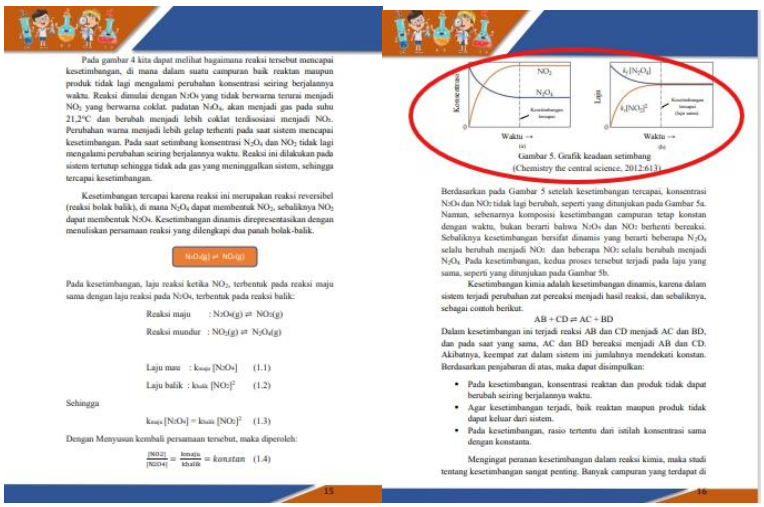


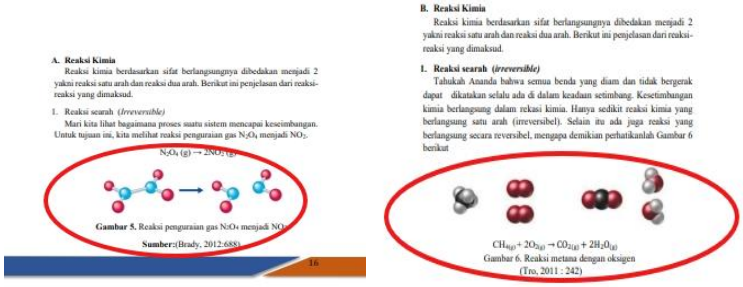
(b)

Figure 5. (a) R Vision before 96 dpi Image Quality and (b) Revision after 350 dpi Image Quality



(a) (b)

Figure 6. (a) R vision before Adding Graphs and (b) Revision after Adding Graphs



(a) (b)

Figure 7. (a) R vision before Replacing other Reaction Examples with Irreversible Reaction Examples and (B) Revision after Replacing Irreversible Reaction Examples

Based on the findings of the construct validity and content validity questionnaires given to five experts, two chemistry teachers at SMA Negeri 8 Padang, and three UNP chemistry lecturers obtained an average score of 0.86 for content validation and 0.87 for construct validation, as seen in Figure 8.

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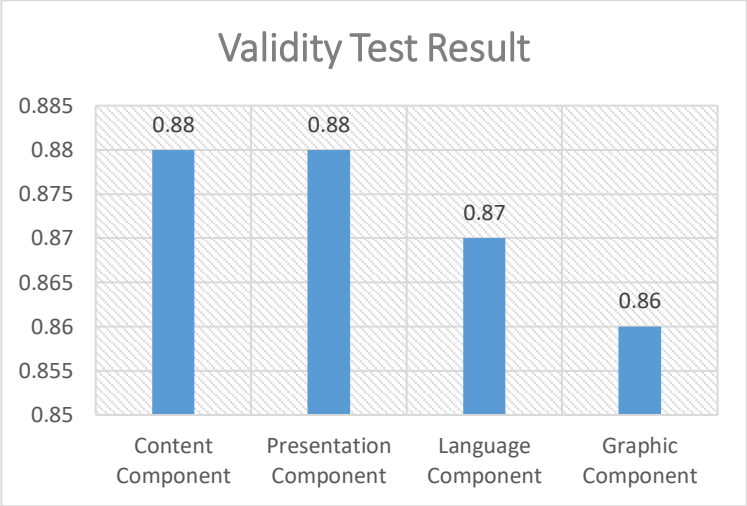

Figure 8. Valid ty Results on Teaching Materials

One-to-one evaluation

At this stage, three-phase F SMA/MA students with varying levels of expertise were interviewed (Delfianza et al., 2023). At this stage, three-phase F SMA/MA students with varying levels of expertise were interviewed by students in phase F of SMA Negeri 8 Padang; it can be analyzed that the design's cover and appearance are easy-to-understand teaching materials and a clear appearance. Then, the presentation of material, language, and material components in teaching materials makes Items that include teaching materials that make the subject matter simpler for pupils to comprehend the subject matter. Next, the product pictures on the presented teaching materials are attractive, made of chemical equilibrium material, and have no difficulty using teaching materials. The following is the researcher's documentation at the one-to-one evaluation stage.

Figure 9. Stage *One to Evaluation*

Prototype IV

The next stage is prototype IV, which conducts a small group test to obtain practical results on teaching materials. This small group test is applied by giving a practicality questionnaire to 2 chemistry teachers at SMA Negeri 8, then nine students based on different levels. The practicality exam will be divided into four sections: appearance, convenience of

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use, learning effectiveness, and benefits of teaching materials. The practicality test results will be calculated as a percentage. The subsequent outcomes in Figure 10 display the teachers' and students' practicality test scores.

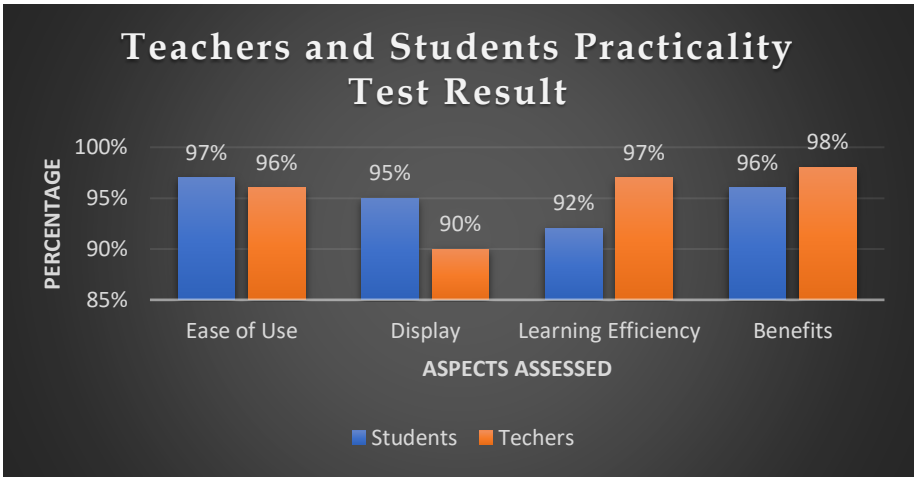

Figure 10. Teach r and Student Practicality Test Results

In addition, this teaching material contains chemical multi-representations, as seen in Figure 11, which can be used as a bridge to help students recognize and understand the concepts taught (Luthfi & Mawardi, 2024). Students can better understand concrete and abstract chemical materials using multirepresentations (Rusiani et al., 2019). By observing the model, students can visually understand the equilibrium process and reach an equilibrium state. Chemistry textbooks with multiple representations of chemistry benefit students with different levels of primary abilities. Chemi al representation is significant for understanding chemical ideas in forming students' mental models (Halim et al., 2013). There are three levels of multirepresentation in chemistry learning. Figure 12 illustrates the connection between three levels of multi-representation and mental models.

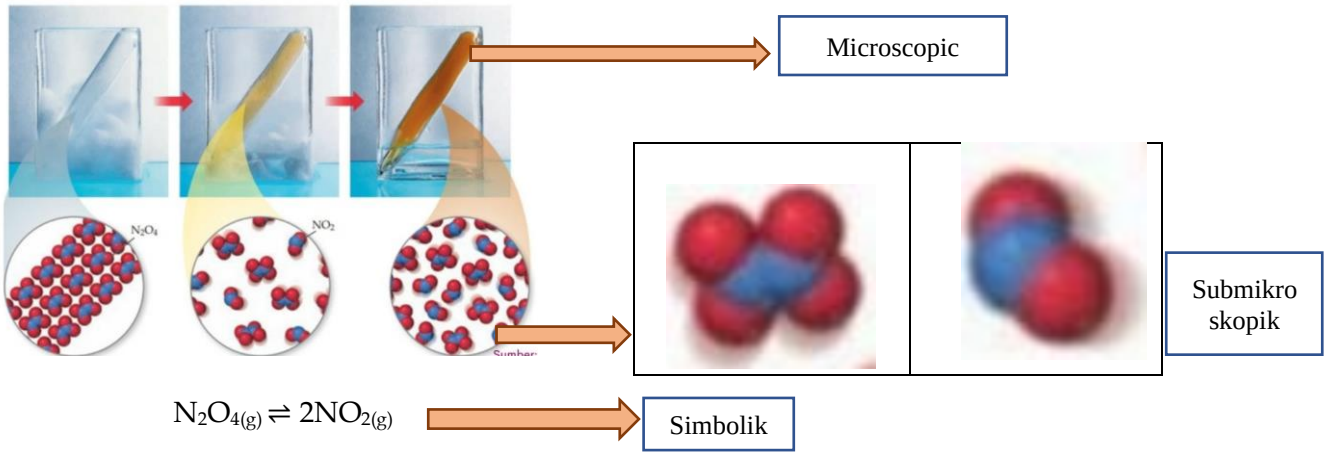

Figure 11. Multi-Representation Model in Teaching Materials

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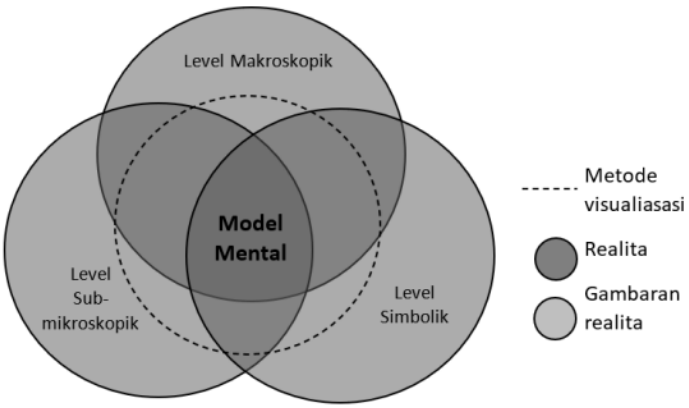

Figure 12. Relationship between Mental Models and Multirepresentation (Halim et al., 2013)

Figure 11 is one of the multirepresentations on the concept of reaction equilibrium $N_2O_{4(g)} \rightleftharpoons 2NO_{2(g)}$ reaches equilibrium. Nature, reach, tents, and products no longer experience changes in concentration over time. Chemi al equilibrium is defined as "When both the forward and reverse reaction speeds, as well as Reactant and product concentrations, are equivalent," according to the findings of student interviews, will be constant"(Chang, 2010). Consequently, figure 17 illustrates how the idea of chemical equilibrium is adhered to. This stage's objectives are to investigate how students respond to the course materials and to support and mentor them as they develop better mental models that will enable them to connect the three levels.

Discussion

Needs and analysis of context, a literature assessment, and the creation of a conceptual framework were all completed during the preliminary research phase. At the needs analysis stage, an initial study was conducted to identify problems and needs for the teaching materials developed. The school will prepare teaching materials to address various issues that arise in schools. Therefore, there must be a need to produce teaching materials that contain material content that can support learning chemical equilibrium in the Merdeka curriculum. Analysis of needs and context also highlights how crucial it is to provide crucial chemical equilibrium material in the Merdeka curriculum. This need can be met using instructional resources from the Merdeka curriculum. Furthermore, the prototyping phase begins with designing the product's chemical equilibrium materials for teaching material at the prototype I stage. The components of teaching materials are taken into consideration when designing this product.

Furthermore, the prototype II stage contains the stages of revision and evaluation carried out on prototype I. The teaching materials developed will be validated. Then, the teaching materials developed will be validated in the form of a validity questionnaire, which includes four primary languages: visuals, presentation, and content are the components. The

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teaching resources are deemed valid and valuable based on the average Score of 0.86 from the five validators in their overall evaluation.

Based on Figure 8, the content component aspect is considered valid with a value of 0.88. These studies indicate that the teaching material products developed have been adapted to the subject matter and the necessities of the Merdeka curriculum for autonomous learning. This shows that TP and student abilities must appropriately consider the breadth of content and depth of material coverage. The teaching materials developed should be planned according to the applicable curriculum. Then, the demands of the curriculum and learning materials are considered when designing the teaching materials.

The validity value of the presentation's parts was deemed to be valid, with a value of 0.88. These results indicate that the teaching materials are designed to be simple (neat and orderly), attractive regarding the objectives to be achieved, and complete in their components (Depdiknas, 2008).

The validity value of the language component pieces is considered legitimate, with a value of 0.87. These results show that the teaching materials use simple language to improve understanding of concepts and are arranged communicatively to improve student's learning abilities. This is consistent with earlier studies by Waer & Mawardi (2021), which say good language is correct according to Indonesian spelling rules.

The component aspects of the grammar's outputs were deemed valid with a validity value of 0.86. These findings demonstrate that overall, the appearance of graphics in instructional materials is created with images, layouts, and illustrations that are appropriate to grab students' focus throughout the educational process (Nengsih et al., 2019).

Exposure to the results validity data on items in the form of instructional materials; with a score of 0.86, all component aspects are deemed legitimate overall. Although the prototype II stage is valid (Herpika & Mawardi, 2021), it needs some suggestions or input from expert assessments, which will later be improved in teaching material products. This compares instructional materials from expert reviews, both before and after.

In addition, the practicality test showed that the teaching material. In Fi ure 10, the teacher gave a very high practicality score because the teaching materials developed by the author had met the criteria following the assessment instrument (Andromeda et al., 2015). With a value of 96% for teachers and 97% for students, the data analysis results on the ease of use of the created teaching materials are beneficial. These findings suggest that when it comes to instructional materials' usability, they can be understood, clear, and practical for both teachers and students.

The results of practicality in the appearance of the teaching materials made were found to be very practical to use, with a value of 90% for teachers and 95% for students. These results state that the way the instructional materials look is attractive. The teaching materials are related to the cover, overall design, and images displayed.

The results of practicality in the aspect of learning efficiency on teaching materials were found to be very practical to use, with a value of 97% for teachers and 92% for students. These results state that the application of designed and developed teaching materials makes

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time efficient, and teaching materials allow teachers to implement instruction within the allotted time frame.

The results of practicality in the aspect of the benefits of teaching materials were found to be very practical to use, with a value of 98% for teachers and 96% for students. These results state that the teaching materials compiled and developed help students as a learning resource that applies the Merdeka curriculum to enable students to comprehend the idea of chemical equilibrium material during the learning process with ease. Then, the teacher helps direct students in independent learning.

The overall average of the practicality components is described as being very practical, with a value based on the analysis results from the practicality exam for teachers and students of 95% and 95%, respectively. These results show that the teaching material products designed and developed are efficient in every aspect of their assessment.

In light of the stage's conclusions, it was found that the teaching materials' clear and appealing image appearance made it easier for pupils to understand both the language and the subject matter that was employed, which was easy to comprehend. Furthermore, the questions and instructions were straightforward, improving students' ability to locate subjects and turn in answers. Using the teaching materials allowed students to learn. The various multi-representations contained in teaching materials can minimize the occurrence of misconceptions in students' understanding of chemical equilibrium material (Fitriza et al., 2019). The instructional materials in this content, packed with multiple representations, will help students develop mental models for learning.

D. Conclusion

The research results show that teaching materials to support Merdeka curriculum learning on chemical equilibrium material phase F SMA / MA can be developed using the Plomp development model. The development of teaching materials to support Merdeka curriculum learning on chemical equilibrium material phase F SMA / MA is declared valid with a validity value of 0.86. The level of practicality is assessed for the teacher's response of 95% with an efficient category and students' response of 95% with an efficient category.

This shows that the teaching material products designed and developed are valid and very practical. The results of this study indicate that the teaching materials that have been developed can be used and are suitable to support Merdeka curriculum learning on chemical equilibrium material. Then, teaching materials equipped with complete chemical multi-representations can build students' mental models in understanding chemical concepts, especially chemical equilibrium material,

Based on the research, it is recommended that teachers become one of the teaching material options that can be used to support Merdeka curriculum learning, especially regarding chemical equilibrium material. This can help students understand and learn chemical equilibrium material independently. Researchers can apply the results of this research and use them as a reference for developing teaching materials in the teaching process. Future researchers are expected to conduct an effectiveness test on the teaching

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materials for chemical equilibrium materials developed.

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