



Development of Discovery Learning Model Module on Chemical Kinetics Material to Improve Critical Thinking Skills of Phase F Grade XI Senior High School Students

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Abstract: This study aims to develop a chemistry learning module based on the discovery learning model on chemical kinetics material to improve critical thinking skills of grade XI Phase F high school students. This research is a type of development research (Research and Development) that uses the Plomp development model, which consists of three stages: preliminary research, development (prototyping phase), and assessment phase. The preliminary research stage includes needs analysis and theoretical studies as the basis for compiling the module. Furthermore, in the development stage, the module was validated by five experts to assess the feasibility of content, presentation, language, and contextual aspects. The results showed that the developed module had very high validity with an average Aiken's V value of 0.96. The practicality test showed an average value of 98.50%, which is classified as very practical. The effectiveness test produced a significance value of 0.019 (< 0.05), which indicates a significant increase in learning outcomes after using the module. It can be concluded that this discovery learning module on chemical kinetics is valid, practical, and effective in improving students' critical thinking skills. This module can be an alternative contextual teaching material that encourages active and independent learning at the high school level.

Keywords: Chemical kinetics; Critical thinking; Development discovery learning; Learning modules

Introduction

Chemistry is a branch of science that plays a crucial role in supporting the development of technology and science in general. One of the core competencies in chemistry learning at the senior high school (SMA) level is fostering critical thinking skills and a deep understanding of scientific concepts through active and meaningful learning. One essential topic in the 11th-grade chemistry curriculum is chemical kinetics, which discusses reaction rates and the factors that influence them. This topic serves as the foundation for understanding many chemical reactions that occur in

nature and industry, making it crucial for students to study it comprehensively and comprehensively. However, in practice, chemical kinetics is often considered difficult by students (Chairam et al., 2015; Sari et al., 2019), primarily due to its abstract nature and the need to understand interrelated concepts, such as the relationship between concentration, temperature, catalysts, and surface area on reaction rate. Based on the author's interviews with teachers and students at SMA Negeri 1 Lubuk Basung, it was found that many students experience difficulties in understanding this topic. This is due, among other things, to conventional teaching methods and inadequate teaching materials,

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such as relying solely on textbooks, Student Worksheets (LKS), and simple presentation media (Afifah & Junaedi, 2024). Unfortunately, to date, teaching materials in the form of learning modules that support active and independent learning are not yet available at the school.

The textbooks used are often considered too complex, both in terms of language and content, making them difficult for students to understand without direct teacher guidance. This is clearly inconsistent with the spirit of the Independent Curriculum, which emphasizes the importance of flexible, student-centered learning, and encourages independent learning and critical thinking skills. To address these issues, innovation is needed in the development of teaching materials that can facilitate students' independent and active learning. One relevant alternative solution is the use of learning modules based on the discovery learning model. Modules are printed teaching materials designed for independent use by students (Le & Nguyen, 2024; Darling-Hammond et al., 2024). They provide comprehensive information regarding learning objectives, teaching materials, learning activities, and evaluation. Barua & Lockee (2024) and Abdullah et al. (2025), states that a module is a complete learning unit consisting of a series of activities designed to achieve learning objectives effectively and efficiently.

Furthermore, the Sanova et al. (2022), adds that modules can help students learn without relying on others, making them highly suitable for enhancing student learning independence. Furthermore, Pamio et al. (2024), states that the use of modules has been proven to improve student understanding, with learning completion rates reaching 84%. This demonstrates that modules are not only learning aids but also media that can significantly improve the quality of student learning outcomes (Haleem et al., 2022). For modules to truly support active and in-depth learning, they need to be integrated with the discovery learning model (Widnyani & Riastini, 2024). Discovery learning is a learning model that emphasizes the process of searching and discovering concepts by students themselves, both individually and in groups. This model provides space for students to be directly involved in constructing their knowledge through the processes of observing, investigating, classifying, making predictions, drawing conclusions, and solving problems. Santoso et al. (2024), state that discovery learning is a series of learning activities that maximally engage students' abilities to search and investigate systematically, critically, and logically so that they can independently discover knowledge, attitudes, and skills.

This aligns with Retnaningrum & Pamungkas (2024) and Prihatin (2024) opinion, which states that discovery learning is a learning process in which students are given the opportunity to search and

discover the knowledge they will learn. Furthermore, Ningrum et al. (2022), states that discovery learning is a learning process aimed at discovering something new in teaching and learning activities. According to Saepuloh et al. (2021), this model emphasizes the involvement of students' critical thinking skills to analyze and solve problems systematically. Meanwhile, Ungirwalu et al. (2025) and Ramadhana et al. (2025), states that discovery learning is a mental process that involves students' abilities to observe, digest, classify, make predictions, explain, measure, and conclude concepts. With this approach, students are expected to be able to discover the concepts they are learning on their own with guidance from the teacher as a facilitator. In the context of chemical kinetics, discovery learning is a highly appropriate approach because it allows students to directly explore the relationships between variables in chemical reactions (Al Shloul et al., 2024). The learning process becomes more meaningful because students do not simply receive information but are actively involved in constructing understanding based on data and their learning experiences (Marzabal et al., 2018; Jong et al., 2023).

Therefore, the development of discovery learning-based learning modules for chemical kinetics is essential. This module is expected to help students understand the material independently, actively, and deeply, and to develop critical thinking skills, which are essential in science learning. Based on this description, the author proposes a research project entitled: "Development of a Discovery Learning Model Module for Chemical Kinetics to Improve Critical Thinking Skills in Phase F Grade XI Senior High School Students." This research aims to develop a valid, practical, and effective module to support the achievement of chemistry learning objectives, specifically in improving students' critical thinking skills in accordance with the demands of the Independent Curriculum.

Method

This research is a research and development (R&D) study. Research and development is a systematic process aimed at producing a specific educational product and testing its effectiveness (Lee et al., 2017). The product developed in this research is a chemistry module based on the discovery learning model for Phase F students in grade 11 of high school. The development model used is the Plomp model developed by Tjeerd Plomp. This model was chosen because it has systematic, directed stages and is appropriate for the context of educational product development. The Plomp model consists of three main phases: Preliminary Research; Development or Prototyping Phase; Assessment Phase.

Research Procedure

The following is a summary of the product development procedure based on the Plomp model used.

Table 1. Product development procedure

Fase	Criteria	Activity Description
Preliminary Research Phase	Content validity	Context analysis and literature review. The outcome of this phase is the initial module design.
Development or Prototyping Phase	Construct validity and practicality	Development, formative evaluation, and revision are based on validation and pilot testing results.
Assessment Phase	Effectiveness	Effectiveness is tested through student pre-tests and post-tests.

Research Stages (Research Procedure)

This research uses the Plomp development model, which consists of three main stages: preliminary research, development or prototyping, and assessment. These three stages are interrelated and aim to produce a valid, practical, and effective product. In the preliminary research phase, two main activities were conducted: a contextual needs analysis and a literature review. The contextual needs analysis was conducted to uncover real-world problems, particularly in the learning process of chemical kinetics. This activity was conducted through interviews and questionnaires with chemistry teachers and students in grade XI phase F. The goal was to identify the obstacles faced by students in understanding the material and the extent of the need for learning materials in the form of learning modules based on the discovery learning model. After the needs data was analyzed, the next stage was a literature review, aimed at deepening theories relevant to product development. The literature review covered four main aspects: the concept and characteristics of learning modules, the theoretical basis of discovery learning, the structure of chemical kinetics material according to the curriculum, and the concept and indicators of students' critical thinking skills (Fareza et al., 2024).

The next stage is the development or prototyping phase. At this stage, researchers begin designing and developing learning modules based on the results of the previous stage. Prototype design is carried out by determining teaching materials, identifying basic competencies and designing appropriate learning activities, preparing reference sources, identifying learning objectives, and developing relevant assessment formats and types. After the initial module prototype is completed, a formative evaluation is conducted through several stages. The first stage is self-evaluation, in which researchers independently evaluate the completeness

and consistency of the designed module content. The next stage is expert validation (expert review), conducted by validators competent in the fields of materials, media, and language. Input and suggestions from experts are used as the basis for module revisions to improve the validity of the content and presentation. After expert validation, the module's practicality is tested by users, namely teachers and students.

Table 2. Self-evaluation sheet indicators

Criteria	Indicator	Statement Number
Content Suitability	Alignment with Learning Objectives	1 and 2
	Material Accuracy	3, 4, 5, 6, 7, 8, 9, 10, and 11
	Encouraging Curiosity	12 dan 13
Presentation Suitability	Presentation Techniques	14
	Presentation Support	15 and 16
	Learning Presentation	17, 18 and 19
Language Suitability	Coherence and Sequence of Thought Flow	20
	Straightforward	21 and 22
	Communicative	23
Contextual Suitability	Dialogic and interactive	24
	Conformity with Language Rules	25
	Straightforward	26
	Communicative	27, 28, 29, 30, 31, 32,
	Dialogic and interactive	and 33
	Conformity with Language Rules	

Table 3. Material validity indicators

Indicators	Statement Number
Material Validity	1, 2, 3, 4, 5, 6, 7, 8, 9
Graphics	10, 11, 12, 13, 14

Table 4. Teacher practicality indicators

Indicators	Item Number
Usable	1-5
Easy to use	6-9
Appealing	10-13
Clear	14-17

Table 5. Student practicality indicators

Indicators	Item Number
Ease of Use	1-4
Attractiveness	5-8
Display Efficiency	9
Benefits	1-12

Practicality testing by teachers was conducted to obtain feedback on the module's ease of use, clarity of content, and usefulness in the learning process. Meanwhile, practicality testing by students was conducted in three stages: one-on-one, small group, and further evaluation, if necessary. In the one-on-one phase, a trial was conducted with three students to gauge initial

responses to the module's use. Next, in the small group phase, a trial was conducted with nine students randomly selected based on high, medium, and low ability categories. Student feedback served as a basis for further revisions to the module, until it reached the desired practicality level. The final phase was the assessment phase, which aimed to assess the effectiveness of the developed module in improving students' critical thinking skills. Assessment was conducted by comparing the results of pretests and posttests given to students before and after using the module in the learning process. Differences in learning outcomes were analyzed quantitatively to determine the extent to which students' understanding and skills improved after using the discovery learning module. This analysis serves as an important indicator in determining the module's effectiveness as a product suitable for use in chemistry learning in schools. Data Collection Instruments. Several instruments used in this study are outlined in Tables 3-5.

Data Analysis Techniques

In this study, the researcher will use data analysis techniques by collecting data, then processing and analyzing it. The goal is to produce information related to the quality of the developed learning media.

Preliminary Research Stage

According to Susantara & Myartawan (2020), teacher and student questionnaire data can be analyzed using the following formula:

$$\text{Mark} = \frac{\sum \text{Score obtained}}{\sum \text{Maximum score}} \times 100\% \quad (1)$$

Meanwhile, data analysis from teacher interviews was processed by summarizing the interview results.

Development/Prototyping Phase

Validity Analysis Technique

For validity analysis, the researcher used Aiken's formula, where data obtained from the validator was entered into the formula to obtain the validity results of the developed learning media. The formula used is as follows:

$$V = \frac{\sum s}{[n(c - 1)]} \quad (2)$$

Where:

s = r - lo

lo = lowest validation assessment score

c = highest validation assessment score

r = score given by an assessor

n = Number of data or number of validators

Table 6. Learning media validation level categories

Achievement Level	Category
≥ 0.90-1.00	Valid
≤ 0.90	Invalid

Practicality Analysis Technique

Data on the practicality of the developed learning media was obtained from teacher and student questionnaires. The data obtained were analyzed using the following formula:

$$\text{Practical Value} = \frac{\sum \text{Score obtained}}{\sum \text{Maximum score}} \times 100\% \quad (3)$$

Table 7. Categories of practicality of learning media

Achievement Level (%)	Category
81-100	Very Practical
61-80	Practical
41-60	Quite Practical
21-40	Less Practical
< 20	Not Practical

To measure the effectiveness of the module, a quantitative approach was used by comparing students' pretest and posttest results before and after using the module. Prior to the effectiveness test, prerequisite tests were conducted, namely the normality test and the homogeneity test. The normality test was conducted to determine whether the data were normally distributed using SPSS version 21. Data were considered normally distributed if the significance value (Asymp. Sig. 2-tailed) was > 0.05. Furthermore, the homogeneity test aimed to ensure that the data obtained from the student group had homogeneous variance. The decision was made that the data were considered homogeneous if the significance value for "Based on Mean" was > 0.05. After the data met the assumptions of normality and homogeneity, a hypothesis test was conducted to determine whether there was a significant difference between the pretest and posttest scores. Hypothesis testing was performed using parametric statistics if the data were normally distributed and homogeneous, or using nonparametric statistics if the data did not meet these requirements. The decision-making criteria were: if the significance value was < 0.05, then Ho was rejected, indicating a significant improvement in student learning outcomes after using the module. Conversely, if the significance value is > 0.05, then Ho is accepted, meaning there is no significant difference between before and after using the module.

Results and Discussion

Research Results

This research was conducted based on Putri et al. (2024) and Fauzi & Habibah (2025) development model,

which consists of three stages: preliminary research, development/prototyping, and assessment. Each stage was designed to produce a valid, practical, and effective discovery learning-based chemistry learning module that enhances the critical thinking skills of eleventh-grade students in phase F.

Results of the Preliminary Research Phase

The initial stage of this research consisted of a contextual needs analysis and a literature review. Based on interviews with chemistry teachers at SMAN 1 Lubuk Basung, it was revealed that the learning process currently relies on textbooks and conventional teaching materials, and that resources and facilities are limited. Furthermore, teachers recognize the importance of utilizing more innovative learning media appropriate to the material's characteristics, but the lack of discovery learning-based modules remains a major obstacle. The questionnaires and interviews with students revealed that most students expressed difficulty understanding chemistry material, including chemical kinetics. Students stated that they relied more on teacher explanations and experienced difficulties when required to study independently using the available textbooks. Although most students had never used learning modules or the discovery learning method, they demonstrated interest and enthusiasm for this new learning method. The results of the needs analysis were then supported by a literature review related to four main components: the concept of modules as independent learning materials, the theory and application of the discovery learning model, the structure of reaction rate material in chemical kinetics, and indicators and development of students' critical thinking skills.

Development/Prototyping Phase Results

The module was developed through a prototype design process containing key components, including: cover, foreword, table of contents, user manual, module description, learning outcomes and objectives (CP and TP), discovery learning steps, concept maps, and material descriptions and learning activities. This module is designed to guide students in independently understanding the concept of reaction rate and the factors that influence it through a discovery-based approach.

Formative Evaluation and Validation

During the self-evaluation phase, researchers reflected on the module's content, visual appearance, and language. Two major weaknesses were identified: inconsistent language use and an unattractive visual design. These two areas were then revised before expert validation. The expert validation phase was conducted

by five validators from the fields of chemistry education, media design, and language. The validation results were analyzed using Aiken's V formula and are presented in Table 8.

Table 8. Module validity test data

Aspects assessed:	Aiken's V value
Content suitability	0.94
Presentation suitability	0.96
Language suitability	0.96
Contextual suitability	0.96
Average	0.96

Based on Table 8, all aspects received an average score of 0.96, indicating that the module is valid and suitable for use in learning.

Practicality Test Results

The practicality test was conducted to determine the extent to which the module could be used easily and engagingly by both teachers and students. The test was conducted in four stages: by the teacher, one-on-one (3 students), and small group (9 students).

Table 9. Teacher practicality test data

Aspects Assessed	Mark (%)
Useful	96
Easy to Use	95
Attractiveness	100
Clarity	100
Average	98

Table 10. One-to-one practicality test results

Aspects Assessed	Mark (%)
Ease of Use	100
Attractiveness	95
Display Efficiency	100
Benefits	100
Average	99

Table 11. Results of the small group practicality test

Aspects Assessed	Mark (%)
Ease of Use	100
Attractiveness	95
Display Efficiency	100
Benefits	100
Average	99

Table 12. Summary of student practicality tests

Test Type	Mark (%)
One-to-One	99
Small Group	99
Average	99

Table 13. Summary of teacher and student practicalities

Respondents	Mark (%)
Teachers	98
Students	99
Average	99

These results indicate that both teachers and students considered the developed module highly practical for use in learning.

Effectiveness Test Results (Assessment Phase)

The module's effectiveness was tested to determine the extent to which the use of discovery learning-based learning modules impacted student learning outcomes. Measurements were made by administering pretests and posttests to two groups of students: the experimental class (using the module) and the control class (not using the module). Before further analysis, statistical prerequisite tests, namely normality and homogeneity tests, were conducted to ensure that the data met the criteria for using parametric tests. The results of the normality test using the Kolmogorov-Smirnov method showed that the posttest scores from both groups had a significance value greater than 0.05. This indicates that the data distribution for both groups is normal, allowing for further parametric statistical analysis.

Furthermore, the results of the homogeneity test showed that the significance value was also greater than 0.05, indicating that the variance between groups was homogeneous. With these two requirements met, the effectiveness analysis continued using the t-test (independent sample t-test). Based on the t-test results, a significance value of 0.019 ($p < 0.05$) was obtained, indicating a significant difference in learning outcomes between the experimental and control groups. This means that students who studied using the discovery learning-based learning module achieved better learning outcomes compared to students who did not use the module. Thus, it can be concluded that the developed module is effective in improving student learning outcomes, especially in chemical kinetics material.

Discussion

Preliminary Research Stage

The results of the preliminary research stage indicate that teachers and students experienced various obstacles in the chemistry learning process. Teachers stated that limited facilities and teaching materials were the main obstacles to developing contextual and interactive learning (Osman & Suryawati, 2017; Abdurrahmansyah et al., 2022). Meanwhile, students found it difficult to understand chemistry material due to its abstract nature and the lack of engaging and easy-

to-understand learning media (Iyamuremye et al., 2024; Laliyo et al., 2023). This is supported by the opinions of Menno & Prodjosantoso (2025) and Mukhlisin (2024), who emphasized the importance of providing visual media and contextual teaching materials in chemistry learning. Students' responses to the discovery learning approach were also quite positive, even though they had never used it before. They showed high enthusiasm because this method provided opportunities for active and independent learning. This aligns with Hanani (2020) and Kamaluddin & Widjajanti (2019), theory, which states that meaningful learning occurs when students are directly involved in discovering concepts.

Development Stage

The learning module was developed based on the results of the needs analysis and the theoretical foundation of discovery learning. This module was systematically designed, covering all important learning components such as learning outcomes, objectives, learning steps, student activities, reflection, and evaluation. Expert validation was conducted to ensure that the module met the criteria for content, presentation, language, and contextuality. Validation results indicated that the module was highly valid (Aiken's V score > 0.90). The module was designed in print format for easy access by all students, with an attractive visual design and language appropriate to students' cognitive levels. Validation was conducted by nine experts, and all aspects received excellent scores. This demonstrates that the module is suitable for classroom testing.

Practicality Test

The results of the practicality test conducted with teachers and students showed that the module was very easy to use, engaging, efficient, and provided real benefits in the learning process. The practicality score from teachers reached 98%, and from students reached 99%. The module was considered to support active student engagement and increase their interest in learning. The visual presentation, integrated content, and coherent activity structure made the module suitable for independent use by students (Kusumantoro et al., 2022; Fitri et al., 2024).

Effectiveness Test

The effectiveness of the module was tested through pretests and posttests. The test results showed a significant increase in student scores in the experimental class compared to the control class. The t-test yielded a significance value of 0.019 (< 0.05), indicating that the module effectively improved student learning outcomes. This module not only presents the material in an engaging and interactive manner but also encourages

students to think critically and relate the material to everyday life (Haryanti et al., 2025; Daryanes et al., 2023). Thus, this discussion confirms that the discovery learning-based learning module developed is valid, practical, and effective in improving critical thinking skills and learning outcomes in Grade XI Phase F students in Chemical Kinetics (Sari et al., 2023; Kholistiyawatin et al., 2023).

Conclusion

Based on the research results and discussions, it can be concluded that this study successfully produced a product in the form of a discovery learning model-based learning module on chemical kinetics, designed to improve the critical thinking skills of 11th-grade Phase F students in high school. The module development process adhered to the Plomp development model, which includes preliminary research, development, and assessment. The developed module underwent validation by five validators consisting of material, media, and language experts, and the results indicated that the module was categorized as highly valid. Furthermore, practicality tests conducted with teachers and students indicated that the module had a very high level of ease of use and usefulness. The practicality score reached 98.5%, which is categorized as highly practical, indicating that the module can be used independently by students and significantly supports the classroom learning process. Meanwhile, the module's effectiveness test showed satisfactory results, with significant improvements in student learning outcomes after using the module. This demonstrates that the developed module is effective in improving students' understanding and critical thinking skills, particularly on reaction rates in chemistry.

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Author Contributions

Conceptualization, validation, formal analysis, resources, writing—original draft preparation, visualization, I.Y.; methodology, investigation, data curation, writing—review and editing, A. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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