



Received : 01 February 2026

Revised : 28 April 2026

Accepted : 30 May 2026

Publish : 30 May 2026

Page : 76 – 87

Development of E-Module Based on Higher Order Thinking Skills Integrated with Discovery Learning for Thermochemistry

Mella Amilasti Naila¹, Haqqi Annazili Nasution^{2*}¹Bilingual Chemistry Education Study Program, Chemistry Department,

Universitas Negeri Medan, Medan

*Email: haqqiannazili@unimed.ac.id

Abstract: Learning thermochemistry is often difficult for students due to abstract concepts and complex computational requirements, leading to low engagement and high misconception rates. To address these challenges, this research developed a Higher Order Thinking Skills (HOTS)-based e-module integrated with the Discovery Learning model using the 4D development framework. The e-module was designed as an interactive flipbook utilizing Canva and the Heyzine platform. Results demonstrate that the e-module is highly feasible, with validation scores of 3.32 from media experts and 3.31 from material experts. Response tests yielded very positive results, averaging 3.51 from teachers and 3.27 from students, highlighting its usability and engaging visual design. Implementation significantly improved learning outcomes, as the student mean score rose from 37.57 to 86.52, achieving a Normalized Gain of 0.79, which is categorized as high effectiveness. This success is attributed to the integration of Discovery Learning syntax, which encourages students to construct knowledge independently. By combining digital technology with HOTS-oriented tasks, this e-module serves as an effective instructional tool that successfully bridges the gap between theoretical chemistry and real-world applications in 21st-century education

Keywords: 4D Model; Discovery Learning; E-Module; HOTS; Thermochemistry

INTRODUCTION

Education is a transformative process aimed at developing critical thinking and intellectual maturity, as emphasized in national regulations on science and technology mastery (Rahman et al., 2022). In the 21st century, learners are expected to master the 4C skills: critical thinking, creativity, collaboration, and communication.

They also need digital literacy to address real-world challenges (Karimah et al., 2025). In this context, chemistry plays an essential role as a foundation for many scientific fields (Dewi et al., 2022). However, chemistry learning is still often dominated by rote learning, where students memorize formulas without understanding their application, resulting in weak conceptual understanding (Treagust et al., 2018; Yeni et al., 2024).

Thermochemistry is frequently cited as one of the most challenging topics due to its abstract nature and heavy reliance on computational precision (Agustina et al., 2023; Habiddin et al., 2021). Current data indicates that up to 60% of students struggle with this topic, with error rates in enthalpy calculations reaching 93% (Agustina et al., 2023). Observations at SMAN 2 Medan reveal a significant gap. Current instruction relies heavily on conventional textbooks and passive lectures. This approach fails to connect abstract concepts with real-world applications (Nasution et al., 2025). To address this gap, this research proposes the development of an Electronic Module (e-module) based on Higher Order Thinking Skills (HOTS) integrated with Discovery Learning. Unlike standard digital textbooks, e-modules provide an immersive, interactive environment that facilitates independent learning and visualizes abstract chemical reactions (Dewi et al., 2021; Erna et al., 2021). The integration of HOTS ensures students move beyond rote learning to analyze and evaluate phenomena (Adella et al., 2024), while the Discovery Learning model provides a structured, inquiry-based framework through stages such as stimulation and verification (Hasanah & Prayogo, 2023). This synthesis of a digital platform with a student-centered pedagogical model represents a significant contribution to modernizing chemistry instruction.

The general objective of this study is to develop a valid, practical, and effective HOTS-based e-module integrated with the Discovery Learning model for thermochemistry instruction. The specific objectives are as follows. First, to determine the feasibility of the e-module based on media and material expert validation scores. Second, to analyze teacher and student response ratings regarding the e-module's usability and design. Third, to evaluate the improvement in students' HOTS learning outcomes using normalized gain (N-Gain) analysis.

Based on the theoretical framework and previous studies, the null hypothesis (H_0) states that there is no significant improvement

in students' HOTS learning outcomes after using the HOTS-based e-module integrated with Discovery Learning on thermochemistry, while the alternative hypothesis (H_a) states that there is a significant improvement. Therefore, this study uses a one-tailed statistical test because the direction of the expected effect is positive (improvement in learning outcomes).

LITERATURE REVIEW

2.1 The Nature of Learning and Chemistry Education

Learning is a fundamental process that supports the development of human potential and improves the quality of human resources (Nurhidayati et al., 2023). It is a conscious effort to help students actively explore and develop their abilities (Syafii, 2023). In science education, chemistry plays an important role. It provides a systematic way to understand natural phenomena through observation, experimentation, and analysis (Salsabil et al., 2024).

Science learning includes three main dimensions: product, process, and scientific attitude (Syazali & Umar, 2022). The product refers to facts and theories. The process involves scientific inquiry. The scientific attitude includes honesty and persistence. At the senior high school level, chemistry learning aims to help students master these dimensions to solve real-world problems (Karimah et al., 2025).

2.2 Twenty First-Century Learning and Higher Order Thinking Skills

Modern learning requires students to develop essential skills. These include critical thinking, creativity, collaboration, and communication (Khusna et al., 2023; Scott, 2023). These skills help students adapt to changes and solve complex problems (Sakdiyah, 2025).

Higher Order Thinking Skills (HOTS) are a key part of this process. HOTS include analyzing, evaluating, and creating (Adjijaya et al., 2023). These skills encourage students to think beyond memorization (Setyawan et al., 2023). In chemistry, HOTS are important because many concepts are abstract. Students

need to connect theory with experiments using logical reasoning (Saputra et al., 2025).

2.3 Development of Learning Media and the E-Module

Educational research development is a systematic process of designing and evaluating learning products to ensure they are effective and practical for classroom use (Rindrayani et al., 2025). The 4D model, consisting of the Define, Design, Develop, and Disseminate stages, serves as a foundation for creating digital learning media due to its clear and adaptable structure (Yusuf, 2023; Fauziah, 2025).

A prominent innovation in this field is the electronic module or e-module, a digital version of self-instructional material enriched with multimedia and interactive features (Famulaqih & Lukman, 2024). E-modules offer flexibility and higher interactivity through the integration of text, visuals, audio, and animation, making them better suited for modern blended learning environments (Erna et al., 2021). These tools foster motivation and deeper understanding by visualizing abstract chemistry concepts that are otherwise difficult to comprehend (Dewi et al., 2022; Purnamasari et al., 2020).

2.4 Discovery Learning Model

Discovery Learning focuses on student-centered learning. Students actively discover concepts through exploration (Sundari & Fauziati, 2021). This model is based on constructivist theory, where students build their own understanding (Azizah et al., 2025). The stages include stimulation, problem statement, data collection, data processing, verification, and generalization (Nugroho & Wardani, 2025). These steps guide students to think critically and systematically. Students are trained to test ideas and draw conclusions (Nuryakin, 2025). Integrating Discovery Learning with HOTS in e-modules creates active learning. It also increases motivation and supports deeper understanding (Manurung & Pappachan, 2025).

2.5 Thermochemistry

Thermochemistry studies energy changes in chemical and physical processes

(Ramli et al., 2022). It is based on the First Law of Thermodynamics, which states that energy cannot be created or destroyed. Energy can only change form.

Energy changes in reactions are expressed as enthalpy change (ΔH). Heat is released in exothermic reactions and absorbed in endothermic reactions (Ramli et al., 2022). Understanding these concepts helps students relate chemistry to real-life processes such as combustion and photosynthesis.

2.6 Research Gap and Conceptual Framework

Previous studies show several gaps. First, many e-modules are descriptive and lack HOTS-based tasks (Adella et al., 2024). Second, Discovery Learning is rarely integrated into e-modules for thermochemistry (Hasanah & Prayogo, 2023). Third, most studies focus on feasibility and do not measure effectiveness using N-Gain (Dewi et al., 2021; Erna et al., 2021; Pardosi & Dibyantini, 2025). Fourth, based on the literature search, no previous study has combined the 4D model, HOTS, Discovery Learning, and N-Gain in a single design.

This study addresses these gaps by developing a HOTS-based e-module integrated with Discovery Learning using the 4D model. E-modules improve understanding and engagement (Fadhilah & Nasution, 2025). They also increase motivation and learning outcomes (Lumban Gaol et al., 2025). HOTS is important because students' higher-order thinking is still low (Sitorus & Jahro, 2024). Problem-based digital learning also improves achievement in complex topics (Fadhilah & Nainggolan, 2024). Discovery Learning supports active and deeper learning (Karan, 2023).

METHODS

3.1 Research Location and Time

This study was conducted at SMA Negeri 2 Medan, selected due to its adequate digital learning infrastructure and its implementation of the Merdeka Curriculum, which emphasizes student-centered learning. The research was carried out from October

2025 to January 2026, encompassing preparation, development, implementation, and completion of the research report.

3.2 Population and Sample

The population consisted of approximately 430 Grade XI Science students at SMA Negeri 2 Medan in the 2025/2026 academic year. A simple random sampling technique was applied to ensure equal selection opportunity. The selected sample was Class XI-Mendel 1, consisting of 33 students.

3.3 Research Design

This study employed a Research and Development (R&D) approach using the 4D development model proposed by Thiagarajan, Semmel, and Semmel (1974), as cited in Sugiyono (2019). The model consists of four stages: Define, Design, Develop, and Disseminate.

The study focused primarily on the first three stages (Define, Design, and Develop), while the Disseminate stage was conducted on a limited scale due to contextual constraints. To evaluate the effectiveness of the developed e-module, a One-Group Pretest–Posttest Design was used. Students' learning outcomes were measured before (pretest) and after (posttest) the implementation of the e-module.

3.4 Research Instruments

The instruments used in this study consisted of test and non-test instruments. The test instrument comprised 20 validated multiple-choice questions designed to assess students' cognitive learning outcomes at the HOTS levels (C4–C6).

The non-test instruments included validation sheets completed by media and material experts to evaluate content quality, technical functionality, and scientific accuracy. In addition, teacher and student response questionnaires were used to assess the attractiveness, usability, and effectiveness of the e-module using a 4-point Likert scale, where 1 = strongly disagree, 2 = disagree, 3 = agree, and 4 = strongly agree.

3.5 Data Collection Techniques

Data were collected using both test and non-test techniques. The test technique

involved administering pretests and posttests to measure students' improvement in learning outcomes objectively. The non-test techniques included expert validation sheets and response questionnaires to obtain qualitative data related to feasibility, practicality, and user acceptance of the developed e-module.

3.6 Research Procedure

The research procedure followed the stages of the 4D development model.

1. The Define stage focused on identifying learning problems through teacher interviews and student needs analysis questionnaires.
2. The Design stage involved preparing the e-module blueprint, including content structure, layout, visualization, and interactive features.
3. The Develop stage included the production of the e-module, expert validation, revisions, and a limited field trial.
4. The Disseminate stage involved the distribution of the validated e-module to teachers and students at SMA Negeri 2 Medan as a digital learning resource.

3.7 Data Analysis Techniques

Data obtained from expert validation and response questionnaires were analyzed by calculating the mean score of each assessment aspect.

$$\bar{\Sigma} = \frac{\Sigma X}{N} \quad (1)$$

Where :

$\bar{\Sigma}$ = Mean score

ΣX = Total score

N = Number of Items

The mean scores were interpreted using the following criteria.

1. 3.26–4.00 (very feasible),
2. 2.51–3.25 (feasible),
3. 1.76–2.50 (less feasible), and
4. 1.00–1.75 (not feasible)

An e-module is considered feasible if the mean score falls into the very feasible or feasible category.

The effectiveness of the e-module in improving students' learning outcomes was analyzed using the normalized gain (N-Gain)

formula proposed by Hake (1999), as cited in Hayati et al. (2020) as follows :

$$g = \frac{S_{post} - S_{pre}}{S_{max} - S_{pre}} \quad (2)$$

where :

g = N-gain score

S_{pre} = Pre-test score

S_{post} = Post-test score

S_{max} = Maximum possible score (100)

The N-Gain values were classified into :

1. High ($g \geq 0.70$),
2. Moderate ($0.30 \leq g < 0.70$), and
3. Low ($g < 0.30$).

RESULT AND DISCUSSION

4.1 Results

The development of a Higher Order Thinking Skills (HOTS)-based e-module integrated with Discovery Learning on thermochemistry was conducted as a solution to learning challenges commonly encountered in chemistry instruction. The e-module was developed using Microsoft Word for content preparation, Canva for visual design and layout, and the Heyzine platform for digital publication in the form of an interactive flipbook. The development process followed the 4D model, with emphasis on the Define, Design, and Develop stages, while dissemination was conducted on a limited scale.

4.1.1 Define Stages

The define stage revealed that students experienced difficulties in thermochemistry concepts requiring both conceptual understanding and numerical calculation. Teacher interviews and student needs analysis questionnaires confirmed that existing learning resources were limited and predominantly teacher-centered, while students demonstrated high readiness for interactive digital learning media. Based on these findings, an e-module format integrated with Discovery Learning syntax was selected and designed.

4.1.2 Design Stages

The design stage focused on planning a HOTS-based e-module integrated with Discovery Learning for thermochemistry.

This phase involved determining the appropriate media, structuring the module format, and developing research instruments to ensure the product meets pedagogical and technical standards.

1. Media Selection

Media selection was informed by front-end analysis, teacher interviews, and student needs. Findings indicated a requirement for interactive, digital-based media that supports conceptual understanding, problem-solving, and higher-order thinking skills in thermochemistry.

An electronic module was chosen as the primary medium, developed using Microsoft Word for content, Canva for visual design, and the Heyzine platform for publishing. This combination ensures the e-module is visually engaging, user-friendly, and easily accessible across various devices.

2. Format Selection

The e-module utilizes an A4 format to maintain readability for both digital and printed use. The structure is organized into four primary sections designed to support the Discovery Learning model and improve material navigation.

Preliminary Section

This section serves as a navigation aid and includes the cover, a foreword explaining the module's purpose, and comprehensive lists of contents, figures, and tables.



Figure 1. Preview of Preliminary Section

Introduction Section

The introduction outlines the module identity, Learning Objectives Flow (ATP), and the integration of the Pancasila Student Profile. It also features a thermochemistry concept map and specific usage guides for both teachers and students to ensure smooth implementation.

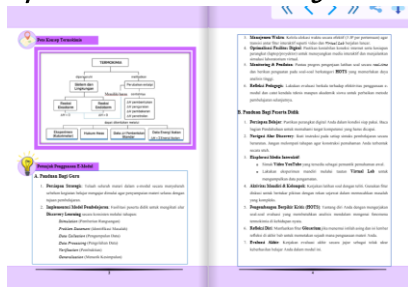


Figure 2. Preview of Introduction Section

Thermochemistry Learning Activities

The core content is divided into three meetings: Basic Concepts, Thermochemical Equations, and Enthalpy Change determination. Each meeting follows the Discovery Learning syntax, guiding students through stimulation, data collection, and verification phases.

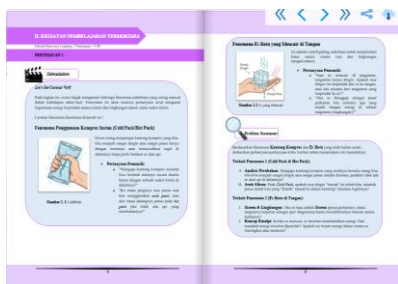


Figure 3. Preview of Learning Activities Section

Evaluation and Supporting Features

To reinforce learning outcomes, the final section includes a summary, a glossary of scientific terms, and HOTS-based final evaluations. It also incorporates reflection tools and academic references to support independent student learning.

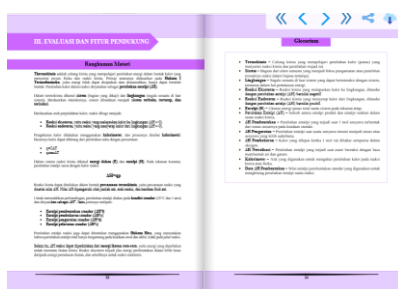


Figure 4. Preview of Evaluation and Supporting Section

4.1.3 Develop Stage

1. Media Expert Validation Results

The feasibility of the developed e-module was evaluated by three media experts. The validation results are presented in **Table 1**.

Table 1. Media Expert Validation Results

No	Aspect	Mean	Category
1	Visual Design Quality	3.20	Feasible
2	Functionality and System Performance	3.50	Highly Feasible
3	Learning Integration	3.27	Highly Feasible
Overall		3.32	Highly Feasible

The results indicate that the e-module is technically sound, with particularly high marks in functionality. With an overall score of 3.32, the media is considered highly feasible for instructional use.

2. Material Expert Validation Results

The feasibility of the developed e-module was evaluated by three material experts. The validation results are presented in **Table 2**.

Table 2. Material Expert Validation Results

No	Aspect	Mean	Category
1	Content Feasibility	3.27	Highly Feasible
2	Presentation Feasibility	3.33	Highly Feasible
3	Language Feasibility	3.33	Highly Feasible
Overall		3.31	Highly Feasible

According to the experts, the content is robust and well-structured. The overall mean of 3.31 confirms that the material is educationally sound and ready for implementation in a classroom setting.

3. Teacher Responses

Following the expert validations, the e-module was reviewed by educators to determine its practicality in a real-world teaching environment. Teachers provided feedback on how the module assists in delivery and classroom management.

Table 3. Teachers Responses' Results

No	Aspect	Mean	Category
1	Attractiveness	3.40	Very Practical

2	Usability	3.56	Very Practical
3	Effectiveness	3.59	Very Practical
Overall		3.51	Very Practical

The teacher responses were positive, especially regarding the effectiveness of the tool. An overall score of 3.51 suggests that the e-module is a highly practical asset for modern teaching workflows.

4. Students Responses

The e-module was tested by students to gauge the end-user experience. This assessment measured the module's appeal and how easily students could navigate the lessons independently.

Table 4. Students' Responses' Results

No	Aspect	Mean	Category
1	Attractiveness	3.32	Very Practical
2	Usability	3.20	Practical
3	Effectiveness	3.29	Very Practical
Overall		3.27	Very Practical

Students found the e-module engaging and helpful for their studies. While usability received a "Practical" rating, the overall score of 3.27 classifies the module as "Very Practical" for student-centered learning.

5. Improvement in Learning Outcomes

The effectiveness of the HOTS-based e-module was measured by comparing student performance before and after the learning process. A pretest was administered to determine initial knowledge, followed by a posttest to evaluate the improvement in understanding thermochemistry concepts.

Table 5. N-gain Score

Test	Mean Score	N-gain	Category
Pretest	37.57		
Posttest	86.52	0.79	High

The data shows a significant increase in the mean score from 37.57 to 86.52. With an N-gain score of 0.79, the improvement is classified in the "High" category, demonstrating that the e-module is highly effective in helping students master the

material and develop higher-order thinking skills.

4.2 Discussion

The development of the HOTS-based e-module for thermochemistry follows a systematic design and evaluation process that confirms its quality and instructional effectiveness. Based on the validation and trial results, the discussion focuses on three key pillars: technical feasibility, pedagogical practicality, and impact on student learning.

4.2.1 Feasibility of E-Module

The high media feasibility score (3.32) was primarily driven by the functionality aspect (3.50). This reflects the stable performance of the Heyzine flipbook platform, which preserves interactive elements such as clickable navigation and embedded multimedia. Unlike conventional PDFs that often lose interactivity across different devices, the flipbook format ensures consistent user experience, reducing technical barriers that could distract students from learning.

From the material perspective, the high score (3.31) was evenly distributed across content, presentation, and language. This indicates that the integration of HOTS-based questions and Discovery Learning syntax was well-aligned with the Kurikulum Merdeka. Specifically, the Discovery Learning stages (stimulation, data collection, verification) provided a natural scaffold for HOTS tasks, allowing students to build understanding incrementally. These findings are consistent with previous studies reporting that interactive e-modules using Discovery Learning obtain high feasibility ratings due to strong pedagogical alignment and technical quality (Abidin & Wulandari, 2022; Lasala, 2023).

4.2.2 Practicality Based on Teacher and Student Responses

Teachers rated the module as very practical (3.51), with effectiveness receiving the highest score (3.59). This suggests that the e-module reduced teacher workload by providing ready-to-use HOTS questions and structured Discovery Learning activities. Teachers no longer needed to design inquiry-

based tasks from scratch, which is time-consuming. Students rated the module as very practical (3.27), though usability (3.20) was slightly lower than attractiveness (3.32). This gap likely stems from students' initial unfamiliarity with flipbook navigation, particularly using zoom and page-flip features. However, after the first meeting, students adapted quickly, as reflected in the posttest improvement.

This result aligns with previous studies reporting that Discovery Learning-based e-modules demonstrate high practicality due to their interactive features, clear presentation, and flexibility for both classroom and independent learning contexts (Aladin et al., 2024; Aryani & Kurniawati, 2022).

4.2.3 Improvement in Learning Outcomes

The effectiveness analysis confirms the impact of the e-module on learning outcomes. The mean score increased from 37.58 (pretest) to 86.52 (posttest). The N-Gain value of 0.79 falls into the high category based on Hake's criteria. These findings indicate that the learning intervention facilitated meaningful learning and reduced learning gaps among students with varying initial ability levels. This result is consistent with previous studies reporting high N-Gain values for Discovery Learning-based chemistry e-modules (Luthfiani & Yerimadesi, 2022; Aryani & Kurniawati, 2022).

Therefore, the null hypothesis (H_0) is rejected, and the alternative hypothesis (H_a) is accepted. This means that there is a significant improvement in students' HOTS learning outcomes after using the HOTS-based e-module integrated with Discovery Learning on thermochemistry.

CONCLUSION

This study confirms that the HOTS-based e-module integrated with Discovery Learning is a feasible, effective, and practical digital learning resource for thermochemistry instruction. Expert validation results demonstrate high feasibility, with mean scores of 3.32 from

media experts and 3.31 from material experts. The implementation of the e-module resulted in a substantial improvement in students' learning outcomes, as indicated by the increase in mean scores from 37.58 (pretest) to 86.52 (posttest) and a high average N-gain value of 0.79. Positive responses from teachers (mean = 3.51) and students (mean = 3.27) further indicate that the e-module is attractive, easy to use, and effective in supporting learning activities.

The findings have important implications for the advancement of educational technology in science learning. The integration of Higher Order Thinking Skills and Discovery Learning within an interactive e-module demonstrates how digital media can be systematically designed to promote higher-level cognitive processes and active knowledge construction. This study contributes to the development of technology-enhanced chemistry education by providing an empirically validated instructional model that can be adapted for other abstract and calculation-intensive science topics, supporting the broader implementation of student-centered and digitally driven learning environments. This study has limitations, including a single-school sample (33 students) and limited dissemination scope. Future research should expand the sample size and test the e-module on other abstract chemistry topics.

ACKNOWLEDGEMENT

The authors would like to thank the thesis supervisor, Haqqi Annazili Nasution, M.Pd., and the thesis examiners for their guidance and constructive feedback. Appreciation is also extended to the validators for their professional evaluations during the e-module development. The authors acknowledge the chemistry teachers, school management, and students of SMA Negeri 2 Medan, particularly Class XI Mendel 1, for their cooperation and participation. Special thanks are given to Universitas Negeri Medan (UNIMED), the Department of Chemistry, and the Bilingual

Chemistry Education Study Program for providing academic support and facilities.

REFERENCE

- Abidin, Z., & Wulandari, T. C. (2022). The Model of AnalyticaSI Geometry Interactive Module using Systematic, Active, Effective (SAE) Model to Support Students' Autonomous Learning and Mathematics Education Competence. *American Journal of Humanities and Social Sciences Research*, 6(5), 76–80. www.ajhssr.com
- Adijaya, M. A., Widiana, I. W., Parwata, I. G. L. A., & Antara, I. G. W. S. (2023). Bloom's Taxonomy Revision-Oriented Learning Activities to Improve Procedural Capabilities and Learning Outcomes. *International Journal of Educational Methodology*, 9(1), 261–270.
- Aladin, Asrowi, & Santosa, E. B. (2024). Analysis of the Need for Problem-Based Learning E-Modules to Enhance High Order Thinking Skills (HOTS) Among High School Students. *International Conference on Science and Technology for the Internet of Things*, 1(01), 630–649.
- Aryani, D. R., & Kurniawati, D. (2022). Entalpi Pendidikan Kimia Efektivitas E-Modul pada Materi Sistem Koloid Berbasis Discovery Learning terhadap Hasil Belajar SMA/MA. *Entalpi Pendidikan Kimia*, 2(2), 18–24.
- Azizah, M., Zahra, F., Muzfrah, S., & Mubarak, F. (2025). *Model Pembelajaran: Konsep, Paradigma dan Implementasi*. Penerbit Adab.
- Dewi, C. A., Pahriah, P., & Purmadi, A. (2021). The Urgency of Digital Literacy for Generation Z Students in Chemistry Learning. *International Journal of Emerging Technologies in Learning*, 16(11), 88–103. <https://doi.org/10.3991/ijet.v16i11.19871>
- Dewi, S., Pramono, A., & Fathurrahman, D. (2021). Motivational factors in chemistry learning: A case study in high school students. *Jurnal Pendidikan dan Psikologi Pendidikan*, 9(2), 45–58.
- Dewi, S., Pramono, A., & Fathurrahman, D. (2022). E-learning innovation in science education: A design-based approach. *Jurnal Inovasi Pendidikan Sains*, 8(1), 34–45.
- Fadhilah, N. F., & Nasution, H. A. (2025). Development of chemistry e-modules based on augmented reality technology on hydrocarbon material. *Jurnal Inovasi Pembelajaran Kimia*. 2(1), 124-133. <https://doi.org/10.24114/jipk.v7i1.67921>
- Fadhilah, M., & Nainggolan, B. (2024). The influence of problem-based e-modules on students' motivation and learning outcomes in acid–base material. *Jurnal Inovasi Pembelajaran Kimia*, 6(2), 203-210.
- Famulaqih, S., & Lukman, A. (2024). Pengembangan Bahan Ajar Modul Pembelajaran. *Karakter: Jurnal Riset Ilmu Pendidikan Islam*, 1(2), 1–12.
- Fauziah, M. (2025). Advancing ESP Material Development: An Analytical Approach Using 4D Models. *Journal of English Language Studies*, 10(1), 96–118.
- Habiddin, H., Utari, J. L., & Muarifin, M. (2021). Diagnostic Tool to Reveal Students' Conception on Thermochemistry. *AIP Conference Proceedings*, 2330(March). <https://doi.org/10.1063/5.0043288>
- Hasanah, R., & Prayogo, M. S. (2023). Penerapan Model Pembelajaran Discovery Learning untuk Meningkatkan Hasil Belajar IPA Pada Siswa Kelas V SDN Jatiroto 03 Kecamatan Sumberbaru Kabupaten Jember. *Jurnal Pendidikan Ilmu*

- Pengetahuan Alam (JP-IPA), 4(2), 29–37. <https://doi.org/10.56842/jp-ipa.v4i2.202>
- Hayati, U., Ediyani, M., Maimun, M., Anwar, K., Fauzi, M. B., & Suryati, S. (2020). Test technique as a tool for evaluation of learning outcomes. *Budapest International Research and Critics Institute-Journal (BIRCI-Journal)*, 3(2), 1198-1205. <https://doi.org/10.33258/birci.v3i2.961>
- Karan, E. (2023). Discovery-based approach combined with active learning to improve student learning experiences for STEM students. *International Journal of Education and Humanities*, 3(4), 288-299.
- Karimah, K., Fasifah, F., & Iskandar, Sofyan. (2025). Strategi Pengembangan Pembelajaran Abad Ke-21: Mengintegrasikan Kreativitas, Kolaborasi, dan Teknologi. *JIIP (Jurnal Ilmiah Ilmu Pendidikan)*, 8(1), 109–116.
- Khusna, S. A., Khasanah, I., Musa, M. M., & Rini, J. (2023, July). Kurikulum merdeka belajar melalui pembelajaran abad 21 untuk meningkatkan kompetensi 4C siswa Madrasah Ibtidaiyah N. In *Prosiding SEMAI: Seminar asional PGMI* (Vol. 2, pp. 22–34).
- Lasala, N. (2023). Development and Validation of E-SelfIMO: E-Learning Self-Directed Interactive Module in Earth Science. *Recoletos Multidisciplinary Research Journal*, 11(1), 85–101. <https://doi.org/10.32871/RMRJ2311.01.07>
- Lumban Gaol, A. R. J., Nainggolan, B., & Batu Bara, H. (2025). The effect of problem-based learning and e-modules on student motivation and learning outcomes in hydrocarbons. *Jurnal Inovasi Pembelajaran Kimia*, 7(1), 154-161. <https://doi.org/10.24114/jipk.v7i1.67943>
- Luthfiani, A., & Yerimadesi, Y. (2022). Effectiveness of e-module based on guided discovery learning on learning outcomes of high school students. *Jurnal Pijar Mipa*, 17(6), 770–774. <https://doi.org/10.29303/jpm.v17i6.4252>
- Manurung, A. S., & Pappachan, P. (2025). The role of discovery learning in efforts to develop students' critical thinking abilities. *Journal of Education and Learning (EduLearn)*, 19(1), 46–53.
- Nasution, H. A., Darmana, A., Daulay, R. A., & Kurniawan, E. D. A. (2025). Implementation of a Higher Order Thinking Skills (HOTS)-Based Chemistry Module with a Science, Technology, Engineering, and Mathematics (STEM) Approach on Thermochemistry Material. *Jurnal Riset Ilmu Pendidikan*, 5(2), 285–289. <https://doi.org/10.30596/jcositte.v1i1.xxxx>
- Nugroho, F., & Wardani, E. F. (2025). Penerapan Model Discovery Learning untuk Meningkatkan Hasil Belajar Siswa pada Mata Pelajaran IPAS Kelas IV di SDN 3 Namang. *Jurnal Riset Multidisiplin Edukasi*, 2(5), 149–167.
- Nurhidayati, V., Ramadani, F., Melisa, F., & Putri, D. A. E. (2023). Penerapan Mind MAPPING Sebagai Medis Dalam Meningkatkan Kemampuan Belajar. *Jurnal Binagogik*, 10(2), 99–106.
- Nuryakin, M. P. (2025). *Model pembelajaran discovery learning dan penerapannya*. TATA AKBAR.
- Pardosi, A. S., & Dibyantini, R. E. (2025). Development of E-Modules Based on PBL (Problem Based Learning) Integrated with STEM (Science, Technology, Engineering,

- Mathematic) on Thermochemistry Material. *Jurnal Pendidikan dan Pembelajaran Kimia*, 14(2), 148-160. <https://doi.org/0.23960/jpkv2.14215>
- Rahman, A., Munandar, S. A., Fitriani, A., Karlina, Y., & Yumriani. (2022). Pengertian Pendidikan, Ilmu Pendidikan dan Unsur-Unsur Pendidikan. *Al Urwatul Wutsqa*, 2(1), 1–8.
- Ramli M., Saridewi, N., Mustika Budhi, T., & Suhendar, A. (2022). *Buku Kimia SMA/MA Kelas XI* (Jilid 1). Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi.
- Rindrayani, A., Siregar, R., & Ningsih, D. (2025). Sampling techniques in educational research. *Jurnal Metodologi Pendidikan*, 10(1), 33–47.
- Sakdiyah, S., Widna, W., & Gusmaneli, G. (2025). Integrasi penggunaan teknologi dalam strategi pembelajaran PAI untuk membentuk kompetensi 4C peserta didik era digital. *Dinamika Pembelajaran: Jurnal Pendidikan dan Bahasa*, 2(2), 229–242.
- Salsabil, G. D., Sari, W., Ikmawati, & Kurniawan. (2024). Hakikat Sains: Pengertian, Fungsi, dan Penerapan dalam Proses Pembelajaran. *Jurnal Penelitian Mahasiswa*, 3(4), 37–45. <https://doi.org/10.58192/populer.v3i4.2664>
- Saputra, T., Purnomo, E. A., & Joko, I. (2025). Peningkatan kemampuan higher order thinking skills (HOTS) melalui optimalisasi metakognitif siswa. *Jurnal Ilmiah Matematika (JIMAT)*, 6(1), 196–208.
- Scott, C. L. (2023). The Futures of Learning 3: What Kind of Pedagogies for the 21st Century? *International Journal for Business Education*, 164(1), 2–4. <https://doi.org/10.30707/ijbe164.1.1690386168.68154>
- Setyawan, F. H., Adhira, S. J., & Putra, S. J. (2023). Analisis Kemampuan Berpikir Kritis Mahasiswa pada Pembelajaran Berbasis Artificial Intelligence di Era Merdeka Belajar. *In Social, Humanities, and Educational Studies (SHES): Conference Series*, 8(3).
- Sugiyono. (2019). *Metode penelitian pendidikan: Pendekatan kuantitatif, kualitatif, dan R&D*. Alfabeta
- Sundari, S., & Fauziati, E. (2021). Implikasi Teori Belajar Bruner dalam Model Pembelajaran Kurikulum 2013. *Jurnal sPapeda: Jurnal Publikasi Pendidikan Dasar*, 3(2), 128–136.
- Sitorus, D. P., & Jahro, I. S. (2024). Analysis of students' scientific literacy ability in solving HOTS-based chemistry questions. *Jurnal Inovasi Pembelajaran Kimia*, 6(2), 227-237
- Syafii, I. (2023). Meningkatkan Keterampilan Kolaborasi Siswa melalui Model Pembelajaran berbasis Proyek: Materi Hakikat Ilmu Kimia dan Metode Ilmiah. *Jurnal Pendidikan Indonesia: Teori, Penelitian, Dan Inovasi*, 3(1). <https://doi.org/10.59818/jpi.v3i1.439>
- Syazali, M., & Umar, U. (2022). Peran Kebudayaan Dalam Pembelajaran IPA Di Indonesia: Studi Literatur Etnosains. *Jurnal Educatio FKIP UNMA*, 8(1), 344–354. <https://doi.org/10.31949/educatio.v8i1.2099>
- Treagust, D., Nieswandt, M., & Duit, R. (2018). Sources of students difficulties in learning Chemistry. *Educación Química*, 11(2), 228. <https://doi.org/10.22201/fq.18708404e.2000.2.66458>
- Yeni, F. S., Octarya, Z., & Utami, L. (2024). Analisis Pemahaman Konsep Siswa Kelas XI Pada Materi Termokimia Menggunakan Four Tier Multiple Choice. *Journal of Research and Education Chemistry*, 6(1), 68. <https://doi.org/10.25299/jrec.2024.vol>

Yusuf, M. (2023). Development of Arabic language teaching materials with 4D model for the second semester at STAI Al-Furqan Makassar. *Bulletin of Science Education*, 3(3), 152–170.