

**Received** : 3 June 2025**Revised** : 22 October 2025**Accepted** : 27 October 2025**Published** : 31 October 2025**Page** : 205 – 213**Development E-Module of Process Oriented Guided Inquiry Learning on Thermochemistry**Garvin Brilly Anugerah Simangunsong^{1*}, and Jamalum Purba²^{1,2}Chemistry Education Study Program, Faculty of Mathematics and Natural Sciences,
Universitas Negeri Medan, Medan, Indonesia**Email:* simangunsonggarvin@gmail.com

Abstract: This study aims to develop a thermochemistry e-module based on Process Oriented Guided Inquiry Learning (POGIL) for Grade XI students at SMAN 14 Medan. Based on observations, thermochemistry is considered a difficult topic for students due to the lack of textbooks, learning resources, and appropriate learning media. This research is a development study using the 4D model (Define, Design, Develop, Disseminate). The developed e-module was validated by two chemistry lecturers and one chemistry teacher, and its practicality was tested by 31 students from class XI-3. The initial validation results showed a score of 89.7% for the material aspect and 85.05% for the media aspect, both categorized as very valid. After revisions, the scores increased to 91.8% for the material aspect and 90.8% for the media aspect. The practicality test based on students' responses gained a score of 90.1%, indicating that the e-module is very practical for use in learning. Therefore, the POGIL-based thermochemistry e-module is proven to be valid and practical, and it effectively supports students' interest and understanding in learning thermochemistry.

Keywords: E-module; POGIL; development; thermochemistry; practicality

INTRODUCTION

Education in the era of the Industrial Revolution 4.0 demands the integration of information and communication technology (ICT) in learning to improve the quality of human resources, particularly in enhancing critical thinking skills (Rismayanti et al., 2022). However, critical thinking skills in chemistry remain low, as evidenced by students' difficulties in interpreting data, drawing conclusions, explaining graphs, and comparing chemical concepts (Manik et al., 2020).

Thermochemistry, as a branch of chemistry, is perceived as particularly difficult due to its abstract nature and the variety of concepts it encompasses—such as the law of conservation of energy, endothermic and exothermic reactions, and enthalpy changes. Understanding these concepts requires mastery of multiple levels of chemical representation: macroscopic, microscopic, symbolic, and submicroscopic (Irfandi et al., 2022).

Observations conducted at SMAN 14 Medan (Grade XI) revealed significant challenges in teaching thermochemistry. Teachers still rely on conventional, teacher-

centered approaches, and there is a lack of quality teaching materials, learning resources, and appropriate media. Interviews with students indicated that they experience major difficulties in understanding core concepts such as enthalpy, Hess's law, thermochemical equations, and the distinction between endothermic and exothermic reactions.

These learning difficulties are primarily caused by instruction that focuses on rote memorization rather than meaningful understanding, thereby weakening students' problem-solving and reasoning abilities (Panggabean & Purba, 2021). Contributing factors include both internal issues (e.g., low understanding of chemistry, weak mathematical skills, low motivation) and external issues (e.g., ineffective teaching methods) (Suharto & Kusasi, 2024); (Purwanto et al., 2025)

To address these challenges, the Indonesian government has introduced the Merdeka Curriculum, which emphasizes essential competencies for the 21st century—such as communication, collaboration, digital literacy, and the use of technology in learning (Amalia, 2022). The curriculum encourages the use of digital learning resources, including e-learning and blended learning platforms, to support student-centered and technology-enhanced education (Pulungan & Simamora, 2024).

One promising solution is the use of e-modules, which offer flexible, accessible, and interactive learning experiences. E-modules can be accessed anytime, allow for repeated study, and can be enhanced with multimedia features such as videos, animations, and quizzes. They are especially effective for supporting independent learning and can also serve as engaging instructional tools in the classroom (Dalimunthe & Ginting, 2022).

Although many studies have explored the development of e-modules for various chemistry topics, there is currently a lack of research focused specifically on the integration of Process Oriented Guided Inquiry Learning (POGIL) into

thermochemistry e-modules. POGIL is a student-centered learning model that promotes critical thinking, collaboration, and concept understanding through guided inquiry activities. Previous research, such as that by (Fadilla, 2023) has shown that POGIL-based e-modules are effective and well-received in chemistry education.

Based on these observations and the identified research gap, this study aims to develop a POGIL-based thermochemistry e-module for Grade XI students that can serve as an innovative learning tool aligned with the goals of the Merdeka Curriculum.

LITERATURE REVIEW

A. Research Development

Development research, also known as research and development (R&D), is a research methodology aimed at producing or refining educational products, such as teaching materials, learning strategies, evaluations, and instructional media (Marizal & Asri, 2022) (Ramadanti et al., 2021) (Violadini & Mustika, 2021). According to (Waruwu, 2024), development research typically involves designing, developing, testing, and validating a product. It begins with a needs analysis, often informed by a review of existing materials or approaches, followed by the creation of a more effective solution. One widely used model for development research is the 4D model—Define, Design, Develop, and Disseminate—offering a systematic framework for creating and validating educational tools.

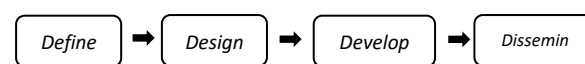


Figure 1. 4D Modeling Development

B. E-Modules

E-modules are structured, electronic learning resources that support independent and flexible learning. They are typically enriched with multimedia elements such as videos, images, and quizzes to foster engagement and deepen understanding. According to (Hermansyah et al., 2023), e-

modules are designed systematically, creatively, and innovatively to include learning methods, materials, and assessments that motivate students to achieve learning goals. They fall under the broader category of e-learning due to their reliance on digital and communication technologies.

(Mutmainnah et al., 2021), highlight several advantages of e-modules, including increased student curiosity and motivation, opportunities for self-evaluation, simplified material organization, adaptability to student ability levels, and flexible usage. (Prasetya, 2021), emphasizes that well-designed e-modules should consider five key learning skills: verbal communication, intellectual abilities, cognitive strategies, attitudes, and motor skills.

Several studies have demonstrated the effectiveness of integrating pedagogical models into e-modules. For example (Panggabean & Purba, 2021) developed Adobe Flash-based e-modules to enhance students' problem-solving skills in chemistry, while (Novianti et al., 2023) incorporated the Problem-Based Learning (PBL) model into e-modules to strengthen students' critical thinking. In another study, (Masy & Lestarani, 2022) integrated ethnoscience into thermochemistry e-modules using HTML5 flipbook software, showing that culturally relevant content can enhance contextual understanding.

C. POGIL

POGIL is a student-centered instructional approach that combines three core components: group learning, metacognition, and guided inquiry. The learning process is structured through a cycle of exploration, concept invention, and application. According to (Putri & Gazali, 2021), the POGIL model includes five stages: Orientation, to stimulate motivation and curiosity; Exploration, where students conduct observations or experiments; Concept Formation, in which patterns are identified; Application, where concepts are applied to

new problems; and Closure, involving conclusion-making and reflection.

Research by (Fadilla, 2023) demonstrated the effectiveness of POGIL in improving learning outcomes. Her study, which developed a POGIL-based e-module for Grade X chemistry, obtained a high validation score of 3.65, indicating strong feasibility for classroom use.

Despite its proven benefits, the integration of POGIL into digital learning tools such as e-modules particularly in complex subjects like thermochemistry remains underexplored.

D. Thermochemistry

Thermochemistry is the study of energy changes, particularly heat, that accompany chemical reactions and physical transformations. It plays a crucial role in helping students understand energy flow in chemical systems. However, its abstract nature makes it challenging for learners. Key concepts include enthalpy change (ΔH), exothermic and endothermic reactions, Hess's law, and bond energy calculations. These require students to interpret phenomena through macroscopic, submicroscopic, and symbolic representations (Irfandi et al., 2022).

(Mahendra et al., 2023) found that students often struggle with calculating enthalpy changes, interpreting reaction data, and applying thermochemical principles to real-world problems. (Suharto & Kusasi, 2024) reported that 70% of students did not understand how to calculate ΔH based on standard enthalpy values, while over 60% had difficulty distinguishing exothermic from endothermic reactions. Similarly, 66.67% of students were unfamiliar with Hess's law, and 55.67% struggled with bond energy calculations due to conceptual misunderstandings.

These findings align with observations at SMAN 14 Medan, where conventional teaching methods and a lack of adequate learning resources have further contributed to students' difficulties with thermochemistry. Most instruction remains teacher-centered,

and students are often passive recipients of knowledge. Interviews revealed confusion surrounding key thermochemistry topics, including enthalpy, Hess's law, and reaction types.

E. Research Gap

Although various studies have explored the development of e-modules and integrated instructional models such as PBL and ethnoscience, there is limited research on the development of thermochemistry e-modules based on the POGIL model. Given the persistent learning difficulties in thermochemistry and the proven effectiveness of both e-modules and POGIL, this presents a clear opportunity for innovation in chemistry education. Developing a POGIL-integrated thermochemistry e-module could offer a meaningful solution to improve student engagement, understanding, and problem-solving skills in this challenging subject area.

METHODS

3.1. Research Location and Time

This research was conducted at SMAN 14 Medan, located at Jl. Siswa Gg. Darmo, Binjai, Medan Denai, Medan City, North Sumatra, 20228, Indonesia. The study took place from February 2025 to April 2025.

3.2. Population and Sample

The population in this study comprised all Grade XI students of SMAN 14 Medan during the 2024/2025 academic year. The sample was selected using a random sampling technique, and Class XI-3 was chosen as the research sample (Pulungan & Simamora, 2024).

3.3. Type and Model of Research

This study employed development research using the 4D model, which consists of four stages:

Define: conducting preliminary analysis, identifying learning problems, and setting learning objectives. Design: designing the structure and content of the e-module based on curriculum and learning needs. Develop: developing the product, validating it through

expert assessment, and revising it based on feedback. Disseminate: disseminating the final product for limited-scale use and evaluating practicality through student responses.

This model was chosen due to its structured approach, combining theoretical foundations with field-based experience in material development.

3.4. Instruments of Data Collection

Several instruments were used in this study:

Table 1. Instrument Data Collection

Instrument	Purpose	Target
Material expert validation sheet	To assess the quality and accuracy of content	2 chemistry lecturers
Media expert validation sheet	To assess design, layout, navigation, and media interogation	1 chemistry teacher
Student response questionnaire	To evaluate the practicaly and user experience	31 student form class XI-3

All instruments used a 4-point Likert scale to avoid neutral responses, encouraging more definitive feedback. The scale interpretation is as follows:

Table 2. The scale interpretation

Percentage Range	Valid Category
85% - 100%	Very Valid
70% - 84%	Valid
55% - 69%	Less Valid
< 55%	Invalid

3.5. Validators

The material aspect of the e-module was validated by two chemistry lecturers, while the media aspect was validated by one chemistry teacher experienced in digital learning tools and interface design.

3.6. Data Analysis Techniques

The data from expert validation were analyzed by calculating the percentage of total scores obtained using the following formula:

$$\text{Percentage} = \left(\frac{\text{Total Score}}{\text{Maximun Score}} \right) \times 100\%$$

The interpretation of validity based on percentage is as follows:

Table 3. Validity base percentage

Interval	Category
0% - 20%	Highly Invalid
21% - 40%	Invalid
41% - 60%	Less Valid
61% - 80%	Valid
81% - 100%	Highly Valid

An e-module is considered feasible for use if it falls into the valid or very valid category. Revisions are made based on validators' comments if necessary (Sholehah et al., 2023); (Suharmita et al., 2024).

The practicality test was conducted through a student questionnaire after the limited implementation of the e-module in class. The responses were also analyzed using a percentage formula and categorized into four levels of practicality, similar to the validity scale.

RESULT AND DISCUSSION

A. Define Stage

The Define stage was conducted at SMAN 14 Medan on May 23, 2025. Through interviews with chemistry teachers and classroom observations in Grade XI-3, several issues were identified students struggle with abstract chemistry concepts, especially in thermochemistry, existing learning resources are limited to textbooks and worksheets, with no supplementary media provided, and students express a preference for interactive media that supports visual, auditory, and kinesthetic learning styles (Rilanty & Juwitaningsih, 2020).

A concept analysis was conducted by reviewing the Independent Curriculum guidelines for thermochemistry, which divides the topic into three learning activities energy and heat, thermochemical equations, and determination of reaction enthalpy These

findings were used to inform the next development phase.

B. Design Stage

At the Design stage, a draft of the thermochemistry e-module was created. The structure was based on: The learning outcomes outlined in the curriculum. Integration of the POGIL (Process Oriented Guided Inquiry Learning) model, with its learning syntax embedded in the module design: Orientation Exploration Concept Formation Application Closure This draft e-module served as the prototype for expert validation and student testing.

Table 1. Draft E-module

No	Draft E Module
1	Cover Page
2	Foreword
3	Table of Contents
4	Module Usage Instructions
5	Concept Map
6	Onboarding Stage
7	Organizing Stage
8	Problem Formulation Stage
9	Tahap Hypothesis
10	Stages of Data Collection
11	Stages of Attraction Conclusion
12	Summary
13	Competency Test
14	Bibliography
15	Answer Key
16	Glossary

C. Development

The material validation was conducted twice before and after revision using a 4 point Likert scale based on BSNP standards for material feasibility. This approach avoids neutral responses and allows for comparison throughout the development process.

Table 2. Material validation before revision

No	Research	Friendly	Validation
1	Content eligibility aspects	89.8%	Highly Valid

2	Aspects of presentation eligibility	88.8%	Highly Valid
3	Contextual assessment	90.6%	Highly Valid
Validation Criteria		89.73%	Highly Valid

Based on the table, the average validator scores were 89.8% for content feasibility, 88.8% for presentation, and 90.6% for contextual aspects, resulting in an overall product validity of 89.7%, categorized as very valid with minor revisions needed. Media validation, also based on BSNP standards and using a 4-point Likert scale, was conducted twice to assess the validity of the POGIL e-module media.

Table 3. Media validation before revision

No	Research	Friendly	Validation
1	Aspects of Graphic Qualification Language	86.1%	Highly Valid
2	eligibility aspects	84%	Highly Valid
Validation Criteria		85.05%	Highly Valid

The average validator scores for graphic feasibility and language feasibility were 86.1% and 84%, respectively, with an overall media validity of 85.05%, categorized as very valid with some recommended improvements.

Table 4. Validation of material after revision

No	Research	Friendly	Validation
1	Content eligibility aspects	92.06%	Highly Valid
2	Aspects of presentation eligibility	90.9%	Highly Valid
3	Contextual assessment	92.6%	Highly Valid
Validation Criteria		91.8%	Highly Valid

After revision after validation, the average percentage of each research component increased and resulted in an average assessment of 91.8% from the initial 89.7% which corresponded to the category of product validity is a very valid category.

Table 5. Media validation after revision

No	Research	Friendly	Validation
1	Aspects of Graphic Qualification Language	90.7%	Highly Valid
2	eligibility aspects	90.9%	Highly Valid
Validation Criteria		90.8%	Highly Valid

After revision after validation, the average percent of each research component increased and resulted in an average assessment of 90.8% from the initial 85.05% which was in accordance with the product validity category which is a very valid category.

D. Disseminate

The response questionnaire contains 18 questions with 4 points filled in 1-4 with the information strongly agree = 4, agree = 3, disagree = 2, strongly disagree = 1.

Table 6. Student response table

Code	Total Score	Maximum Score	Presentase	Category
S1	64	72	89.6 %	Very Practical
S2	72	72	100 %	Very Practical
S3	55	72	77 %	Practical
S4	57	72	79.8 %	Practical
S5	72	72	100 %	Very Practical
S6	57	72	79.8 %	Practical
S7	68	72	95.2 %	Very Practical
S8	64	72	89.6 %	Very Practical
S9	55	72	77 %	Practical
S10	56	72	78.4 %	Practical
S11	62	72	86.8 %	Very Practical
S12	62	72	86.8 %	Very Practical
S13	66	72	92.4 %	Very Practical
S14	66	72	92.4 %	Very Practical

S15	68	72	95.2 %	Very Practical
S16	67	72	93.8 %	Very Practical
S17	67	72	93.8 %	Very Practical
S18	68	72	95.2 %	Very Practical
S19	68	72	95.2 %	Very Practical
S20	68	72	95.2 %	Very Practical
S21	67	72	93.8 %	Very Practical
S22	66	72	92.4 %	Very Practical
S23	60	72	84 %	Very Practical
S24	63	72	88.2 %	Very Practical
S25	69	72	96.6 %	Very Practical
S26	65	72	91 %	Very Practical
S27	67	72	93.8 %	Very Practical
S28	64	72	89.6 %	Very Practical
S29	65	72	91 %	Very Practical
S30	66	72	92.4 %	Very Practical
S31	64	72	89.6 %	Very Practical
Installment –			90.1 %	Very Practical

The average response to the use of e-modules in grades XI-3 of SMAN 14 Medan is 90.1 with a very practical category to be used by students as one of their handles in learning thermochemistry at school.

CONCLUSION

The development of the POGIL-integrated e-module for thermochemistry meets the BSNP standards, as indicated by very valid scores in both the material (initially 89.7%, revised to 91.8%) and media (initially 85.05%, revised to 90.8%) aspects. In addition, students' responses reached 90.1%, placing the e-module in the "very practical" category, indicating a positive reception and ease of use during learning.

These findings suggest that the POGIL-integrated e-module is not only valid but also effective in supporting student learning in thermochemistry. The interactive and inquiry-based design of the module helps address students' difficulties in understanding abstract concepts by providing structured guidance and engaging media. Therefore, this e-module can serve as an innovative and practical learning resource that promotes student-centered learning and can be used to enhance the quality of

chemistry instruction, especially in alignment with the Merdeka Curriculum.

Future research is recommended to explore its effectiveness in different schools and subject areas, or to evaluate its impact on student learning outcomes over time.

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