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VALIDITY AND PRACTICALITY OF STEM-PBL BASED THERMOCHEMISTRY TEACHING MATERIALS FOR CHEMISTRY EDUCATION STUDENTS

Dwy Puspita Sari[1], Mutiara Agustina Nst[2], Dewi Syafriani[3], Alfira Julian Pratiwi[4]
[1,2,3,4] Chemistry Education, Faculty of Mathematics and Natural Science, Universitas Negeri Medan, Medan, Indonesia.

Abstract

This study aimed to develop STEM-PBL-based thermochemistry teaching materials and examine their validity and practicality for use in chemistry education. This research employed a Research and Development (R&D) approach using the ADDIE model, limited to the Analysis, Design, and Development stages. Following product development, expert validation and a limited practicality assessment were conducted. The research subjects consisted of three expert validators and 30 students from the Chemistry Education Study Program. The instruments used were validity and practicality questionnaires employing a four-point Likert scale. Validity data were analyzed using average validation scores, while practicality data were analyzed using the percentage of student responses. The results showed that the developed teaching materials obtained an average validity percentage of 93%, categorized as highly valid. The practicality assessment yielded a percentage score of 92%, categorized as highly practical. Students responded positively to the developed teaching materials, indicating that they were easy to use, attractive, and beneficial for supporting thermochemistry learning activities. The practicality assessment was limited to student responses and did not evaluate learning effectiveness. Therefore, the STEM-PBL-based thermochemistry teaching materials are considered highly valid and highly practical for use in chemistry education.

Keywords: instructional materials, thermochemistry, STEM-PBL, validity, practicality

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[1]**Correspondence Address:**
Chemistry Education, Faculty of Mathematics and Natural Science, Universitas Negeri Medan, Medan, Indonesia
E-mail: dwypuspita@unimed.ac.id

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INTRODUCTION

Educational developments in the 21st century require students not only to understand theory but also to be able to think critically, collaborate, communicate, and solve real-life problems. Therefore, today's learning processes need to be designed to be more active and contextual so that students can connect the material they learn with its application in daily life. In chemistry education, these skills are essential because many chemical concepts are abstract and require a deep understanding (Pan et al., 2021).

Chemistry is a branch of science that studies the structure, properties, and changes of matter, as well as the energy associated with them. Learning chemistry requires students not only to understand concepts theoretically but also to be able to relate those concepts to phenomena occurring in their surroundings (A. Oktaviani et al., 2020). However, in reality, many students still view chemistry as a difficult subject due to the large number of abstract concepts, symbols, and mathematical calculations that must be understood simultaneously (Syafira & Effendi, 2020).

One of the chemistry topics that students often find difficult is thermochemistry. This topic covers energy changes in chemical reactions, such as exothermic and endothermic reactions, changes in enthalpy, and Hess's Law (Simarmata et al., 2025). Students' difficulty in understanding thermochemistry is usually due to the fact that the concepts being studied cannot be directly observed, and instruction still tends to focus on solving mathematical problems. As a result, students tend to memorize formulas rather than fully grasp the underlying concepts (Kasman et al., 2022).

In addition, the teaching of thermochemistry in the classroom is still dominated by lecture-based methods and the use of conventional teaching materials (Dibyantini et al., 2023). The teaching materials used generally consist only of summaries of the subject matter and practice problems, thus failing to provide students with sufficient opportunities to explore concepts independently. This situation results in students being less active during class and tending to struggle with applying thermochemical concepts to real-world situations (Hany & Syafriani, 2024).

Although several studies have reported the implementation of STEM or Problem-Based Learning in chemistry instruction, limited studies have focused on developing thermochemistry teaching materials that systematically integrate STEM components with problem-based learning activities specifically for chemistry education students. Moreover, previous studies have generally emphasized learning implementation and effectiveness, whereas studies examining the validity and practicality of STEM-PBL-based thermochemistry teaching materials at the development stage remain limited. Therefore, this study contributes to the development of a validated and practical STEM-PBL-based teaching material that can support thermochemistry learning in higher education (Husnitha et al., 2023).

According to a study by (Zulaika et al., 2022) the implementation of STEM in chemistry education can enhance students' critical thinking skills and engagement throughout the learning process. The STEM approach also provides a more meaningful learning experience because students are directly involved in the process of investigation and problem-solving. To optimize the implementation of STEM, a learning model is needed that actively engages students in problem-solving. One suitable model is Problem-Based Learning (PBL). The PBL model emphasizes learning through the presentation of contextual problems, thereby encouraging students to seek information, discuss, and find solutions independently. Problem-based learning also helps students develop critical thinking skills and problem-solving abilities (E. Oktaviani et al., 2020).

The integration of STEM with PBL is considered capable of creating more interactive and meaningful learning experiences (Fitriyani et al., 2023). Students not only learn concepts theoretically but are also trained to connect these concepts to real-world situations through investigative activities and problem-solving. The findings of (Mulyati et al., 2024)indicate that STEM-PBL instruction in thermochemistry can enhance student engagement and help students understand concepts more effectively.

In addition, research by (Wahyu et al., 2020) shows that the use of PBL-based teaching materials in thermochemistry can help improve students' conceptual understanding and critical thinking skills. This indicates that the use of teaching materials designed to meet learning needs plays an important role in helping students understand abstract chemistry concepts (Wahyuningsih et al., 2025).

Although previous studies have reported the implementation of STEM and Problem-Based Learning in chemistry instruction, most of these studies focused on learning implementation and its impact on student learning outcomes. Limited attention has been given to the development of thermochemistry teaching materials that systematically integrate STEM components with problem-based learning activities, particularly for chemistry education students at the university level. Moreover, studies examining the validity and practicality of STEM-PBL-based thermochemistry teaching materials remain scarce. This condition indicates a need for the development of instructional materials that are specifically designed to facilitate contextual learning and problem-solving in thermochemistry (Phandini et al., 2023).

Therefore, this study contributes to chemistry education by developing STEM-PBL-based thermochemistry teaching materials and examining their validity through expert validation and their practicality through student responses. The developed teaching materials are expected to provide an alternative learning resource that supports active, contextual, and student-centered learning.

METHOD

This study employed a Research and Development (R&D) approach using the ADDIE model, which consists of Analysis, Design, Development, Implementation, and Evaluation stages. However, the present study was limited to the Development stage, including expert validation, product revision, and a limited practicality assessment. No effectiveness testing was conducted (Ma et al., 2020).

Development Procedure

During the Analysis stage, a needs analysis was carried out through a review of thermochemistry learning problems and existing instructional materials. During the Design stage, the structure and components of the STEM-PBL-based teaching materials were designed. During the Development stage, the teaching materials were produced and subsequently validated by experts. Based on the validators' suggestions, revisions were made to improve the quality of the product. A limited practicality assessment involving 30 Chemistry Education students was then conducted to obtain user responses regarding the usability, attractiveness, clarity, and benefits of the developed teaching materials.

Participant

The research subjects consisted of three expert validators, including two chemistry education experts and one media expert, as well as 30 Chemistry Education students who participated in the practicality assessment.

Research Instrument

The research used instrument was shown in table 1.

Table 1. Research instruments

Aspect	Instrument	Respondent	Indicators
Validity	Validation Sheet	3 Expert Validators	Content, STEM-PBL Integration, Language, Graphics
Practicality	Student Response Questionnaire	30 Students	Ease of Use, Material Clarity, Appearance, STEM-PBL Activities, Benefits

The research instruments consisted of a validation sheet and a student response questionnaire. The validation sheet was used to assess content, STEM-PBL integration, language, and graphic design aspects. Meanwhile, the student response questionnaire was used to assess the practicality of the developed teaching materials in terms of ease of use, material clarity, appearance, STEM-PBL activities, and learning benefits.

Data Analysis

The data analysis techniques in this study consisted of validity and practicality analyses. The validity of the teaching materials was assessed by expert validators, while the practicality of the teaching materials was evaluated based on student responses after using the STEM-PBL-based thermochemistry teaching materials.

Validity data were analyzed using validity percentage formula, while practicality data were analyzed using the percentage of student response scores, with a score of ≥ 81% classified as "very practical." The data analysis techniques in this study consisted of an analysis of the validity and practicality of the teaching materials. The validity of the teaching materials was assessed by expert validators, while the practicality of the teaching materials was assessed based on student responses after using the STEM-PBL-based thermochemistry teaching materials.

The analysis of the validity of the teaching materials was conducted by expert validators using a validation questionnaire. The assessment was conducted using a Likert scale with scoring criteria according to Sugiyono, namely: score 4 = strongly agree, score 3 = agree, score 2 = disagree, and score 1 = strongly disagree. The validity score is calculated using the following formula:

$$\text{Validity Percentage: } \frac{\sum Obtained\ Score}{\sum Maximum\ Score}\ x\ 100\%$$

Table 2. Validity criteria

Percentage (%)	Criteria
81–100	Highly valid
61–80	Valid
41–60	Fairly valid
21–40	Less valid
0–20	Not valid

Teaching materials are deemed suitable for use if they are rated as valid or highly valid. Practicality data were obtained through a student feedback survey after using the STEM-PBL-based thermochemistry teaching materials. The assessment was conducted using a Likert scale with the following scoring criteria: 4 = strongly agree, 3 = agree, 2 = disagree, and 1 = strongly disagree.
The practicality score was calculated using the following formula:
Practicality Percentage: $\frac{\sum Obtained\ Score}{\sum Maximum\ Score}\ x\ 100\%$

Table 3. Practicality criteria

Percentage (%)	Criteria
81–100	Highly practical
61–80	Practical
41–60	Fairly practical
21–40	Less practical
0–20	Not practical

Teaching materials are considered practical if they are rated as "practical" or "very practical" based on student feedback.

RESULTS AND DISCUSSION

Results of the Instructional Materials Validation

The validation of the instructional materials was conducted by three expert validators, who assessed the content, STEM-PBL, linguistic, and graphic design aspects. The assessment used a 1–4 Likert scale. The validation results from each validator are shown in the following table 4.

Table 4. Validation result

No	Assessment Aspect	V 1	V 2	V3	Average	Category
1	Content/Material Aspect	94%	91%	93%	93%	Very Valid
2	STEM-PBL Aspect	96%	93%	95%	95%	Very Valid
3	Language Aspect	92%	89%	91%	91%	Very Valid
4	Graphic Design Aspect	93%	90%	92%	92%	Very Valid
	Overall Average	**94%**	**91%**	**93%**	**93%**	**Very Valid**

The results from the table above can be presented in the graph shown in Figure 1.

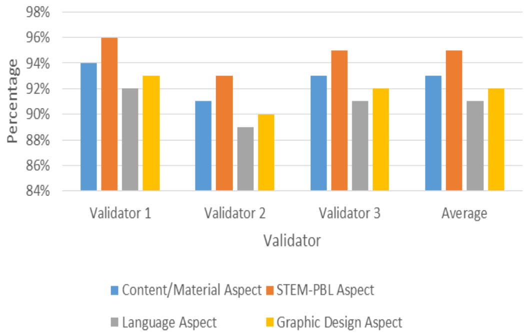

Figure 1. Percentage of validation results by validators

Based on the validation results conducted by three validators, the STEM-PBL-based thermochemistry instructional materials received an average score of 93%, falling into the "highly valid" category. These results indicate that the developed instructional materials have met the feasibility criteria in terms of content, the application of STEM-PBL, language, and graphics. Regarding content, the validators assessed that the material presented aligns with the learning outcomes and is organized systematically, making it easier for students to understand thermochemistry concepts. The example questions and learning activities included in the instructional materials were also deemed relevant to the subject matter being studied.

The high validity score indicates that the developed teaching materials meet the characteristics of quality instructional materials, particularly in terms of content accuracy, instructional design, language clarity, and visual presentation. According to instructional material development principles, learning resources should facilitate students in constructing knowledge independently through meaningful learning activities. The integration of STEM and Problem-Based Learning in the developed materials supports this principle by providing opportunities for students to engage in inquiry, problem-solving, and contextual learning experiences (Elfiza & Hardeli, 2024)

Product Revision

Based on the suggestions provided by the expert validators, several revisions were made to improve the quality of the teaching materials developed. The revisions included improving the clarity of learning instructions, refining scientific terminology, correcting grammatical errors, improving the layout and visual appearance of the materials, and adding supporting illustrations related to thermochemistry concepts. These revisions were intended to enhance the readability, attractiveness, and suitability of the teaching materials before the practicality assessment was conducted.

The STEM-PBL aspect obtained the highest validity score (95%), indicating that the developed teaching materials successfully integrated science, technology, engineering, and mathematics components within problem-based learning activities. The materials provided contextual problems, investigative tasks, and opportunities for students to apply thermochemistry concepts in real-world situations.

This finding is consistent with previous studies reporting that STEM-PBL integration can create more meaningful learning experiences by connecting scientific concepts with real-world problems. Fitriyani et al. (2023) reported that STEM-PBL learning activities encourage active student participation and improve engagement during the learning process. Similarly, Mulyati et al. (2024) found that STEM-PBL instruction in thermochemistry facilitated students' understanding of abstract concepts through contextual problem-solving activities.

The language aspect obtained the lowest score (91%), although it remained within the highly valid category. Validators suggested several improvements related to sentence clarity, terminology consistency, and instructional wording. These suggestions were accommodated during the product revision process.

Although the language aspect obtained the lowest score among the assessed aspects, it still met the highly valid category. This result suggests that the instructional materials were generally understandable for the target users. The revisions recommended by validators primarily focused on improving sentence clarity and terminology consistency, which are important factors in supporting students' comprehension of complex thermochemistry concepts.

In terms of STEM-PBL, the instructional materials were assessed as successfully integrating elements of Science, Technology, Engineering, and Mathematics through contextual, problem-based learning activities. The activities included in the materials also encouraged students to actively discuss, think critically, and collaborate in solving problems. Regarding language use, the language was deemed communicative, easy to understand, and appropriate for the students' developmental level. Meanwhile, regarding the visual design, the presentation of the instructional materials is considered engaging, featuring a systematic layout and the use of images and colors that support the learning process. Based on these results, the STEM-PBL-based Thermochemistry instructional materials are deemed highly valid and suitable for use in chemistry education, with minor revisions as suggested by the validators.

Practicality Assessment Results

A performance assessment was conducted on 30 chemistry education students after they used STEM-PBL-based thermochemistry teaching materials, shown in Table 5.

Table 5. Student performance result

Number	Practicality Aspect	Percentage (%)	Category
1	Ease of use	92%	Very practical
2	Clarity of material	90%	Very practical
3	Appearance of teaching materials	93%	Very practical
4	Suitability of STEM-PBL activities	91%	Very practical
5	Benefits of teaching materials in learning	94%	Very practical
	Average	92%	Very practical

The results from the table above can be presented in the graph shown in Figure 2.

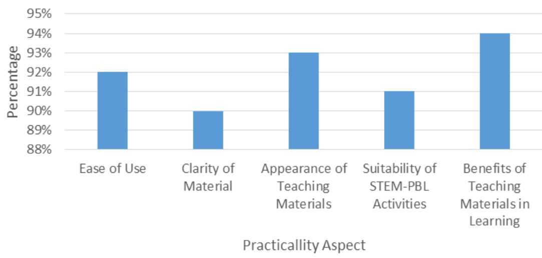

Figure 2. Practicality results of STEM-PBL-based thermochemistry teaching materials

The practicality assessment yielded an average score of 92%, indicating that the developed teaching materials were highly practical. Students responded positively to the usability, appearance, clarity, and benefits of the materials. The highest score was obtained in the benefit aspect (94%), suggesting that students perceived the teaching materials as useful for supporting learning activities. However, the practicality assessment was limited to student responses and did not evaluate the effectiveness of the teaching materials in improving learning outcomes or conceptual understanding.

The high practicality score indicates that students perceived the developed teaching materials as easy to use and helpful in supporting learning activities. Practical teaching materials are characterized by clear instructions, user-friendly organization, and learning activities that can be implemented without significant difficulties. The positive student responses suggest that the developed materials successfully met these characteristics.

The STEM-PBL approach in instructional materials provides a more active learning experience because students not only study theory but also solve contextual problems and engage in simple project-based activities. This makes learning more meaningful and increases student engagement throughout the learning process. Thus, the STEM-PBL-based thermochemistry instructional materials that have been developed meet the criteria of being highly valid and highly practical, making them suitable for use in chemistry education.

This finding supports previous research indicating that STEM-PBL-based instructional resources can increase student engagement and participation during learning activities. Wahyu et al. (2020) reported that problem-based thermochemistry learning materials helped students understand concepts more effectively and promoted critical thinking. Likewise, Zulaika et al. (2022) found that STEM-oriented learning encouraged students to become more actively involved in the learning process through investigation and problem-solving activities.

Research Limitations

This study was limited to the development stage, including expert validation, product revision, and a limited practicality assessment. The implementation and evaluation stages of the ADDIE model were not conducted. In addition, the practicality assessment was based solely on student responses and did not measure the effectiveness of the developed teaching materials in improving learning outcomes, critical thinking skills, problem-solving abilities, or chemical literacy. Therefore, further studies are required to evaluate the effectiveness of the developed teaching materials through broader implementation.

CONCLUSION AND SUGGESTION

Conclusion

The STEM-PBL-based thermochemistry teaching materials developed in this study achieved highly valid and highly practical categories based on expert validation and student response assessments. These findings indicate that the developed teaching materials are feasible for supporting thermochemistry learning in chemistry education. This study contributes to chemistry education by providing a systematically developed STEM-PBL-based teaching material that integrates thermochemistry concepts with contextual problem-solving activities. The product can serve as an alternative instructional resource to support student-centered learning. However, this study was limited to the development, validation, and practicality assessment stages. The implementation and evaluation stages of the ADDIE model were not conducted, and the effectiveness of the teaching materials on learning outcomes, critical thinking skills, and chemical literacy was not examined. Therefore, future studies are recommended to investigate the effectiveness of the developed teaching materials through experimental implementation.

Suggestion

Based on the results of this study, the STEM-PBL-based thermochemistry teaching materials developed are expected to serve as an alternative teaching resource in chemistry education, as they meet the criteria for high validity and practicality. This study is still limited to the stages of validity and practicality; therefore, future researchers are advised to conduct effectiveness tests regarding improvements in learning outcomes, critical thinking skills, and students' chemical literacy. Additionally, the development of STEM-PBL-based teaching materials for other chemistry topics should also be undertaken to make learning more contextual and innovative.

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