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Implementation of a Higher Order Thinking Skills (HOTS)-Based Chemistry Module with a Science, Technology, Engineering, and Mathematics (STEM) Approach on Thermochemistry Material

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ABSTRAK

Pembelajaran kimia memerlukan strategi inovatif guna membantu siswa memahami konsep dengan lebih baik, terutama pada materi termokimia yang sering dianggap sulit. Penelitian ini bertujuan untuk mengevaluasi efektivitas penggunaan modul kimia berbasis Higher Order Thinking Skills (HOTS) dan pendekatan Science, Technology, Engineering, and Mathematics (STEM) dalam meningkatkan hasil belajar siswa. Penelitian ini menggunakan metode kuasi-eksperimen dengan desain pretest-posttest. Subjek penelitian adalah siswa yang mempelajari termokimia dengan menggunakan modul kimia Higher Order Thinking Skills (HOTS) dan pendekatan Science, Technology, Engineering, and Mathematics (STEM). Data dikumpulkan melalui tes pretest dan posttest, kemudian dianalisis menggunakan perhitungan n-gain untuk menilai peningkatan hasil belajar. Hasil penelitian menunjukkan bahwa rata-rata n-gain yang diperoleh sebesar 0,372, termasuk dalam kategori sedang. Temuan ini mengindikasikan bahwa penggunaan modul kimia tersebut dapat membantu meningkatkan pemahaman siswa, meskipun peningkatannya masih belum maksimal. Beberapa faktor, seperti keterbatasan waktu pembelajaran dan kesiapan siswa dalam memahami modul, diduga turut memengaruhi hasil penelitian. Oleh karena itu, diperlukan pengembangan lebih lanjut agar efektivitas modul dapat lebih optimal, misalnya dengan mengintegrasikan metode diskusi dan eksperimen langsung dalam proses pembelajaran.

Keyword: Modul Kimia; HOTS; STEM; Termokimia; n-gain

ABSTRACT

Chemistry learning requires innovative strategies to enhance students' understanding, particularly in thermochemistry, which is often considered challenging. This study aims to evaluate the effectiveness of implementing a Higher Order Thinking Skills (HOTS) and Science, Technology, Engineering, and Mathematics (STEM)-based chemistry module in improving students' learning outcomes. A quasi-experimental method with a pretest-posttest design was employed in this research. The subjects were students learning thermochemistry using the Higher Order Thinking Skills (HOTS) and Science, Technology, Engineering, and Mathematics (STEM)-based chemistry module. Data were collected through pretest and posttest assessments and analyzed using n-gain calculations to measure learning improvement. The results showed that the average n-gain obtained was 0.372, classified as a moderate category. These findings indicate that the chemistry module effectively enhances students' understanding, although the improvement is not yet optimal. Several factors, such as limited instructional time and students' readiness in comprehending the module, may have influenced the results. Therefore, further development is needed to optimize the module's effectiveness, such as integrating discussion-based and hands-on experimental learning methods.

Keyword: Chemistry Module; HOTS; STEM; Thermochemistry; n-gain

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1. INTRODUCTION

Chemistry is often considered a challenging subject due to its abstract concepts and complex calculations (Priliyanti et al., 2021; Kurniawan et al., 2019). One of the most difficult topics for students to grasp is thermochemistry, which involves understanding energy changes in chemical reactions (Irfandi et al., 2022). The abstract nature of this material often leads to misconceptions and difficulties in applying theoretical concepts to real-world situations (Astafani et al., 2024). Therefore, innovative teaching approaches are needed to enhance students' comprehension and engagement in learning thermochemistry.

In the 21st century, education emphasizes the development of Higher Order Thinking Skills (HOTS) to prepare students for problem-solving and critical thinking (H. Nasution et al., 2022). These skills are essential in chemistry learning, enabling students to analyze, evaluate, and create new knowledge rather than merely memorizing facts. One promising approach to fostering HOTS in chemistry education is Science, Technology, Engineering, and Mathematics (STEM), which integrates multiple disciplines to provide a more meaningful and contextual learning experience. Nasution & Setyaningrum (2024) found that STEM Project-Based Learning (STEM-PjBL) significantly enhances HOTS and conceptual understanding, better preparing students for future challenges. Moreover, Wahyuningtyas et al. (2023) demonstrated that Problem-Based Learning (PBL) using a STEM approach positively impacts students' HOTS and learning activities, suggesting that such integrative methods are effective in promoting deeper understanding and engagement in science subjects.

To address the challenges in teaching thermochemistry, this study explores the use of a HOTS-STEM-based chemistry module as an instructional tool. By incorporating STEM principles, this module is expected to help students develop a deeper conceptual understanding and improve their learning outcomes. Previous research has demonstrated that such modules can enhance students' critical thinking skills. For instance, a study developed a HOTS-based chemistry module on thermochemical materials, which was found to improve students' critical thinking abilities (Auliyani et al., 2022). Similarly, the development of a STEM-based integrated chemistry e-module improved students' higher-order thinking literacy in colloid systems (Pertiwi et al., 2024). However, the effectiveness of these modules in enhancing students' comprehension in thermochemistry specifically needs to be examined systematically.

This study aims to analyze the impact of implementing a HOTS-STEM-based chemistry module on students' learning outcomes in thermochemistry. The module is designed to integrate Higher Order Thinking Skills (HOTS) with Science, Technology, Engineering, and Mathematics (STEM) principles, encouraging students to engage in critical analysis, problem-solving, and conceptual exploration rather than relying solely on rote memorization. By incorporating inquiry-based learning, real-world applications, and interdisciplinary connections, this module seeks to enhance students' understanding of thermochemical concepts and their relevance in various scientific and technological contexts. The findings of this study are expected to make significant contributions both theoretically and practically. Theoretically, this research adds to the growing body of knowledge on innovative teaching methodologies, particularly in integrating HOTS and STEM approaches in chemistry education. Practically, it offers educators a structured framework for implementing interactive and student-centered learning materials, ultimately improving engagement, motivation, and academic performance in thermochemistry and other complex scientific topics.

2. RESEARCH METHOD

This study employs a quasi-experimental research design with a pretest-posttest approach to evaluate the effectiveness of the Higher Order Thinking Skills (HOTS) and Science, Technology, Engineering, and Mathematics (STEM)-based chemistry module in improving students' understanding of thermochemistry. The quasi-experimental method was chosen to allow for a controlled comparison between students' initial knowledge and their learning outcomes after using the instructional module.

The research subjects consist of students learning thermochemistry, selected using an appropriate sampling technique, such as purposive sampling or random sampling, depending on the study setting. The selected students participate in the learning process using the Higher Order Thinking Skills (HOTS) and Science, Technology, Engineering, and Mathematics (STEM)-based chemistry module, which serves as the primary teaching material throughout the intervention.

The main research instruments include the Higher Order Thinking Skills (HOTS) and Science, Technology, Engineering, and Mathematics (STEM)-based chemistry module as the primary teaching material, alongside pretest and posttest assessments designed to measure students' learning progress. The pretest is conducted before the intervention to assess students' prior knowledge, while the posttest is administered after completing the learning process to evaluate the effectiveness of the module in enhancing their understanding.

The research procedure involves several stages, beginning with the implementation of the module in the learning process, followed by the administration of the pretest before learning and the posttest after the module has been fully applied. During this phase, students engage with the learning activities structured around the Higher Order Thinking Skills (HOTS) and Science, Technology, Engineering, and Mathematics (STEM) framework, which integrates inquiry-based learning, problem-solving, and interdisciplinary connections.

The categorization of normalized gain (n-gain) scores into three levels—low, medium, and high—originates from research by Hake, (1998), Hake introduced the concept of n-gain to assess the effectiveness of interactive-engagement methods in physics education. He defined the n-gain as the ratio of the actual average gain to the maximum possible average gain, calculated using the formula:

$$g = \frac{\text{Posttest} - \text{Pretest}}{100 - \text{Pretest}} \quad (1)$$

Based on this calculation, Hake proposed the following categories for interpreting n-gain values:
High-g: g≥0.7g
Medium-g: 0.7>g≥0.3
Low-g: g<0.3

These categories have been widely adopted in educational research to evaluate the effectiveness of instructional interventions.

3. RESULTS AND DISCUSSION

A. Implementation of the HOTS-STEM Module

The learning process using the Higher Order Thinking Skills (HOTS) and Science, Technology, Engineering, and Mathematics (STEM)-based chemistry module was conducted to enhance students' understanding of thermochemistry. The module was designed to engage students in higher-order thinking activities, integrating scientific concepts with real-world applications through STEM-based learning. Throughout the implementation, students actively participated in problem-solving tasks, discussions, and hands-on activities aimed at strengthening their conceptual understanding.

Student responses to the module were generally positive, as they found the activities more engaging and relevant compared to traditional learning methods. Many students reported that the structured problem-solving approach helped them analyze and apply thermochemistry concepts more effectively. However, some students faced challenges in adapting to HOTS-based questions, as they were accustomed to rote memorization rather than analytical reasoning.

B. Improvement in Learning Outcomes

To measure the effectiveness of the module, students' learning outcomes were assessed through pretest and posttest evaluations. The average pretest score indicated a relatively low initial understanding of thermochemistry concepts, whereas the posttest results showed a significant improvement after the implementation of the module. The effectiveness of the module in enhancing students' understanding was quantified using n-gain calculations, which categorized the level of improvement into low, medium, and high categories.

Table 1. presents the pretest and posttest scores along with the calculated n-gain values for each student

No	Inisial Peserta	Data Penilaian dan N-Gain		
		Nilai Pretest	Nilai Posttest	N-Gain
1.	AT	55	75	0,44
2	CH	50	75	0,50
3	CI	55	60	0,11
4	EG	55	75	0,44
5	GI	60	65	0,13
6	JO	55	75	0,44
7	JU	50	65	0,30
8	MA	50	65	0,30
9	MO	45	65	0,36
10	NA	45	70	0,45
11	NU	45	60	0,27
12	NZ	40	70	0,50
13	NIR	45	75	0,55
14	PU	50	70	0,40
15	RE	40	65	0,42
16	REV	40	55	0,25
17	REY	40	65	0,42
18	RID	50	75	0,50
19	ROS	40	45	0,08
20	SH	45	80	0,64
21	SY	40	65	0,42
22	TA	50	65	0,30

No	Inisial Peserta	Data Penilaian dan N-Gain		
		Nilai Pretest	Nilai Posttest	N-Gain
23	YS	55	70	0,33
	Overall			0,37213

The average n-gain score was 0.372, which falls within the medium category. This suggests that while the module contributed to better comprehension, further refinements are needed to maximize its impact.

C. Discussion

The improvement in students' learning outcomes, as reflected by the medium-level n-gain, indicates that the Higher Order Thinking Skills (HOTS) and Science, Technology, Engineering, and Mathematics (STEM)-based chemistry module effectively facilitated students' conceptual development. The integration of STEM principles in the learning process allowed students to approach thermochemistry in a more contextual and application-based manner, which aligns with findings from previous studies emphasizing the benefits of HOTS and STEM approaches in science education.

When compared to prior research, similar studies have reported varying degrees of effectiveness in using STEM-based learning materials. Some studies found higher n-gain scores, which could be attributed to longer intervention periods or more interactive teaching strategies. On the other hand, studies with lower gains often pointed to students' difficulties in adapting to higher-order cognitive tasks as a limiting factor.

Several factors influenced the effectiveness of the module, including students' prior knowledge, the duration of implementation, and the level of engagement in STEM-based activities. While the module provided structured guidance, time constraints and students' unfamiliarity with HOTS-oriented questions might have limited their ability to fully grasp the concepts.

Despite its advantages, this study also has certain limitations. The research was conducted on a specific group of students, which may limit the generalizability of the findings. Additionally, the study focused on short-term learning gains, making it necessary to explore long-term retention and application of HOTS skills in future research. Further modifications, such as integrating digital learning tools or collaborative problem-solving activities, could enhance the effectiveness of the module and lead to more significant learning improvements.

4. CONCLUSION

The Higher Order Thinking Skills (HOTS) and Science, Technology, Engineering, and Mathematics (STEM)-based chemistry module has been shown to effectively enhance students' learning outcomes, as reflected in an n-gain score of 0.372, which falls within the moderate category. This module has helped students develop a better conceptual understanding of thermochemistry compared to traditional teaching methods. However, since the improvement is not yet classified as high, further development is needed to optimize its impact on students' comprehension and overall academic performance.

To further improve the module's effectiveness, more engaging and interactive strategies should be integrated, such as virtual laboratory simulations, problem-solving discussions, and the use of digital learning tools. Future studies should involve a broader and more diverse sample population to assess the module's applicability in various educational settings. Moreover, long-term evaluations are necessary to determine its influence on students' knowledge retention and their ability to apply higher-order thinking skills (HOTS) in practical contexts.

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