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Enhancing Critical Thinking Skills Through STEM-Based Guided Inquiry on Reaction Rate

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Abstract

This study aimed to analyze the effect of implementing a STEM-based guided inquiry learning model on students' critical thinking skills regarding reaction rates. Despite the increasing emphasis on critical thinking in science education, limited research has examined how integrated STEM-based instructional models affect students' higher-order thinking skills specifically in abstract and conceptually demanding topics like reaction rates. This study addresses that gap by evaluating the effectiveness of such a model in a real classroom setting. The research employed a quasi-experimental method with a non-equivalent control group design. A total of sixty students from SMA Negeri 1 Bolaang-Uki were selected through purposive sampling. The research instrument consisted of ten essay questions covering critical thinking indicators, validated with a Cronbach's Alpha of 0.706, indicating high reliability. The findings showed that the implementation of the STEM-based guided inquiry model significantly improved students' critical thinking skills. The average pretest score of 10.68% increased to 31.40% in the posttest. Hypothesis testing using an independent-sample t-test resulted in a significance value of 0.000 (< 0.05) with $t_{(count)} > t_{(table)}$ (29.709 > 1.671). Therefore, this study confirms that the STEM-based guided inquiry model is effective in enhancing students' critical thinking skills in learning reaction rate concepts.

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1. INTRODUCTION

Chemistry is a branch of natural science that studies the structure, composition, and changes in matter that occur in everyday life. The purpose of chemistry education is not only to improve students' conceptual knowledge but also to develop critical thinking skills, scientific attitudes, creativity, and responsibility in understanding natural phenomena (Rahmawati et al., 2022). However, the abstract and complex nature of chemistry often becomes a challenge in the learning process, especially in translating theoretical concepts into meaningful understanding (Winarni et al., 2022).

One of the chemistry topics that demands higher-order thinking is reaction rate, which serves as a foundational concept for more advanced topics such as chemical kinetics, equilibrium, and salt hydrolysis. In a recent study, (Herunata, 2025) demonstrated that guided inquiry learning based on Anderson's Learning Sketch Analysis significantly enhanced students' higher-order thinking skills in the reaction rate topic, with students in the experimental group outperforming their peers in analysis, evaluation, and creation skills. Given the experimental nature of chemistry, understanding this topic ideally involves practicum-based learning, both in physical and virtual environments. A meta-analysis by Çalik and Kurt (2024) found that instructional interventions—including inquiry-based learning—had a large positive effect (Hedges' g ≈ 1.04) on students' academic performance in chemical kinetics

Difficulties in learning reaction rates arise from the presence of abstract, unobservable phenomena—such as the relationships between reactant concentration,

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temperature, and catalysts with reaction speed. Additionally, understanding rate equations and reaction order requires students to interpret experimental data and connect multiple interdependent variables (Johnstone, 2006). Therefore, both conceptual and algorithmic skills are essential to develop a deep understanding of this material.

According to (Jusniar et al., 2020), several specific misconceptions about reaction rates—including misbeliefs about how catalysts affect activation energy and the effect of temperature on reaction rate—also contribute to misconceptions in chemical equilibrium, underscoring the importance of addressing these foundational misunderstandings. Fadhilah et al. (2020) also found that misconceptions remain high among students, suggesting the need for more innovative, contextual, and structured learning approaches that actively engage students in reasoning processes.

In response to these challenges, the STEM-based guided inquiry learning model has emerged as a promising solution. The integration of a contextual, student-centered STEM-based guided inquiry approach into chemistry laboratory sessions enhances conceptual understanding and 21st-century skills, with a significant effect size (Cohen's d = 0.8), indicating substantial improvement in higher-order thinking (C4–C6) (Sulastri et al., 2025). Moreover, students' perceptions and responses were positively impacted: 72% of students were actively involved in formulating scientific questions and investigations, which supported their understanding of basic chemical laws (Pohan et al., 2024). Guided inquiry learning also consistently outperforms direct instruction in fostering more expert-like conceptual knowledge (Ghaemi & Mirsaeed, 2017).

Despite the potential benefits of this approach, few empirical studies have specifically investigated the effect of STEM-based guided inquiry on students' critical thinking skills in the context of reaction rate learning. This represents a clear gap in the literature. Therefore, this study aims to fill that gap by analyzing how the STEM-based guided inquiry model can enhance students' critical thinking abilities when learning about reaction rates one of the most conceptually demanding topics in high school chemistry.

2. METHOD

This study employed a quasi-experimental design using a non-equivalent control group with pretest-posttest design. This method enables the comparison of learning outcomes between two groups—an experimental group receiving the intervention (STEM-based guided inquiry model) and a control group undergoing conventional learning—both before and after the learning process. The research was conducted at SMA Negeri 1 Bolaang-Uki during the even semester of the academic year 2024/2025.

Participants in this study consisted of 60 eleventh-grade science students divided into two classes: 32 students in the experimental group (Class XI-A) and 28 students in the control group (Class XI-B). The sampling technique used was purposive sampling, considering practical constraints and the homogeneity of the population in terms of academic level and curriculum exposure.

To assess students' critical thinking skills, a test instrument consisting of 10 essay items was developed. Each item was designed to assess one or more critical thinking indicators as proposed by Facione (2015), covering the five main dimensions outlined above. The instrument underwent expert validation by three chemistry education specialists to ensure content validity and alignment with the curriculum.

Reliability testing was conducted using Cronbach's Alpha, which yielded a coefficient of 0.706, indicating a high level of internal consistency.

Data were collected through pretest and posttest assessments administered before and after the learning intervention. All students were given identical tests under similar conditions. Additional qualitative data such as student worksheets and observation notes were also collected but not analyzed in this study.

Data analysis involved both descriptive and inferential statistics. Descriptive analysis was used to calculate the average percentage score for each indicator before and after the intervention. Inferential analysis is involved. Paired sample t-test to compare pretest and posttest scores within the same group. Independent sample t-test to compare the learning outcomes between the experimental and control groups.

Both tests were conducted using SPSS Statistics version 29. A significance level of $p < 0.05$ was used to determine whether the differences observed were statistically meaningful. The assumptions of normality (Shapiro-Wilk test) and homogeneity of variance (Levene's test) were tested and met prior to hypothesis testing.

3. RESULT AND DISCUSSION

3.1. Result

This study aimed to examine the impact of the STEM-based guided inquiry learning model on students' critical thinking skills in the topic of reaction rates. Students' critical thinking ability was measured through pretest and posttest. The results of pretest and posttest in the control and experimental class based on critical thinking ability indicators are shown in Tabel 1.

The results from the pretest and posttest clearly show that the experimental group, which was taught using the STEM-based guided inquiry model, demonstrated more significant improvements in their critical thinking skills compared to the control group. This section explores the reasons behind this difference, focusing on the specific elements of the STEM-based guided inquiry model that contributed to enhanced critical thinking abilities.

Table 1. Pretest and posttest based on critical thinking ability indicators.

Indicators	Control Group Posttest (%)	Experimental Group Posttest (%)
Providing elementary Clarification	71.5	83.5
Essential support	70.8	79.1
Inferences	52.7	74.5
Advanced Clarification	63.4	75.6
Strategy and Tactic	69.3	81.2

In this study, hypothesis testing was conducted to assess the effectiveness of the STEM-based guided inquiry learning model on students' critical thinking skills. The data was analyzed using both independent samples t-tests and paired samples t-tests, following prerequisite tests for normality and homogeneity.

The results of the normality test, which was carried out using the Shapiro-Wilk method, indicated that all data groups (control and experimental classes, pre-test and post-test) were normally distributed, with significance values above 0.05. Specifically, the control pre-test had a significance of 0.076, the control post-test 0.204, the experimental pre-test 0.090, and the experimental post-test 0.069, confirming that the assumption of normality was met.

Next, the homogeneity of variances was tested using Levene's Test, which showed that all significance values were above 0.05, suggesting that the variances in the pre-test and post-test data for both the control and experimental groups were homogeneous. This fulfilled the assumption of homogeneity and allowed for the continuation of hypothesis testing.

Once these assumptions were validated, hypothesis testing was performed using both the independent samples t-test and paired samples t-test. The independent t-test results revealed a highly significant difference between the control and experimental groups after the intervention, with a p-value of 0.000 ($p < 0.05$) and a mean difference of 5.234. This confirms that the experimental group, which received the STEM-based guided inquiry model, demonstrated superior performance in developing critical thinking skills compared to the control group.

Additionally, a paired samples t-test was conducted within the experimental group to compare their pre-test and post-test scores. The results were highly significant, with a p-value of 0.000 ($p < 0.005$) and a mean difference of 20.719. The 95% confidence interval for this difference ranged from 19.296 to 22.141, indicating a substantial improvement in the experimental group's critical thinking skills after the intervention.

3.2. Discussion

One key reason for the experimental group's success is the integration of STEM disciplines. The STEM-based guided inquiry model encourages students to draw from science, technology, engineering, and mathematics to solve real-world problems. This interdisciplinary approach challenges students to apply knowledge across multiple domains, fostering higher-order thinking skills such as analysis, synthesis, and problem-solving. By connecting theoretical knowledge with practical applications, students learn not only to recall facts but also to critically evaluate and integrate information from different fields. Research by Beers (2014) supports the idea that STEM integration significantly improves critical thinking by requiring students to synthesize knowledge from diverse areas to formulate comprehensive solutions to complex problems.

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This integration encourages students to think critically about how different disciplines can inform one another, providing a more holistic understanding of the subject matter.

Moreover, the STEM-based guided inquiry model emphasizes active learning, a crucial element in developing critical thinking skills. Students in the experimental group were encouraged to take a more active role in their learning, exploring concepts, asking questions, and drawing conclusions based on evidence. This approach is grounded in constructivist theory, which posits that learners build knowledge through active engagement with the material, rather than passively receiving information. By fostering an environment where students can inquire, investigate, and collaborate, the guided inquiry model facilitates deeper understanding and reflection, both of which are essential for critical thinking. As Prince (2004) highlights, active learning encourages students to engage with content at a deeper level, helping them to develop the skills needed to analyze and assess information critically. This level of engagement was not present in the control group, which likely explains why the experimental class showed more substantial gains in critical thinking.

In addition, the model's focus on problem formulation is another significant factor in enhancing critical thinking. The STEM-based guided inquiry model requires students to identify problems, formulate hypotheses, and analyze data in a manner that reflects real-world situations. This process pushes students to approach problems systematically, evaluate various perspectives, and consider potential outcomes before reaching a conclusion. This aligns with Hmelo-Silver's (2004) argument that problem-based learning, a key feature of guided inquiry, fosters critical thinking by engaging students in authentic problem-solving tasks. By confronting real-world challenges, students develop a more nuanced understanding of the problem at hand, as well as the tools necessary to address it. This process also helps them refine their ability to evaluate different perspectives and make well-informed decisions, all of which are essential elements of critical thinking.

Furthermore, data analysis and argumentation played an integral role in developing students' critical thinking skills. The experimental group was encouraged to analyze data, draw conclusions, and support their reasoning with evidence. This emphasis on data analysis and argumentation is essential for developing critical thinking, as it requires students to evaluate the credibility of their sources, assess the validity of their claims, and consider alternative explanations. Facione (2015) highlight the importance of constructing and defending arguments, as this ability is central to critical thinking. In the experimental group, students showed significant improve-ment in providing advanced explanations, demonstrating that they had internalized the process of using evidence to support their claims. This process of argumentation, coupled with data analysis, is crucial for fostering critical thinking, as it challenges students to question assumptions, evaluate evidence, and construct logical, coherent arguments.

Finally, the STEM-based guided inquiry model encouraged reflection, which is another critical component in developing critical thinking skills. Reflection enables students to evaluate their thought processes, identify potential biases, and refine their ideas over time. This reflective process is essential for deepening students' understanding of concepts and strengthening their ability to think critically. Lalumia (2021) emphasized that reflection is a fundamental aspect of critical thinking, as it allows learners to assess their reasoning and make informed decisions. By providing students with opportunities to reflect on their learning experiences, the guided inquiry model helped them develop a more comprehensive understanding of the concepts being taught, ultimately enhancing their critical thinking abilities.

These findings indicate that the STEM-based guided inquiry learning model had a positive and significant impact on improving students' critical thinking skills. The rejection of the null hypothesis (H_0) in both the paired-sample t-test and independent-sample t-test further supports this conclusion, with t-count values of 10.876 (paired) and 29.709 (independent) being far greater than the critical t-value of 1.671. Overall, both statistical tests consistently demonstrate the effectiveness of the STEM-based guided inquiry learning model in enhancing students' critical thinking.

The results of this study highlight the effectiveness of the STEM-based guided inquiry learning model in enhancing critical thinking. The significant improvement in critical thinking skills observed in the experimental group can largely be attributed to the interdisciplinary nature of the STEM model, which integrates science, technology, engineering, and

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mathematics. This integration not only deepens students' understanding of each individual discipline but also challenges them to apply knowledge from these diverse fields to solve complex problems.

STEM integration encourages problem-based learning, which is central to developing critical thinking skills. By engaging in real-world problem-solving, students are required to analyze problems from multiple perspectives, synthesize information from various sources, and develop solutions that are both logical and well-supported by evidence. According to Hmelo-Silver (2004), problem-based learning is a powerful strategy for fostering critical thinking because it requires students to engage in active learning and self-directed inquiry. In this study, the experimental group's engagement with the STEM model provided them with opportunities to practice these skills, leading to significant improvements in critical thinking.

Another critical aspect of the STEM-based guided inquiry model is its emphasis on active learning. The model encourages students to take ownership of their learning through exploration, investigation, and reflection. Research by Prince (2004) has shown that active learning strategies promote deeper cognitive engagement, which is essential for the development of critical thinking. The guidance provided by the teacher during the inquiry process helps students gradually build their critical thinking skills, allowing them to analyze information critically, make informed decisions, and present reasoned arguments.

Additionally, the structured stages of the guided inquiry model, such as orientation, exploration, concept discovery, application, and conclusion, were pivotal in developing critical thinking skills. At each stage, the model encourages students to engage with the material in a way that fosters critical reflection and deepens their understanding. For example, during the exploration phase, students were actively involved in the process of building basic skills and independently exploring new concepts, which helped them develop critical thinking abilities. According to Dewi (2020), the exploration phase is crucial for preparing students to think independently and organize their understanding systematically. By guiding students through these phases, the STEM-based inquiry model ensured that they developed the necessary skills to analyze, evaluate, and synthesize information.

The model's approach to problem formulation and data analysis also played an important role in enhancing students' critical thinking. As students were encouraged to formulate their own questions and hypotheses, they practiced problem-solving and data interpretation, which are essential components of critical thinking. According to Facione (2015), the ability to evaluate and interpret evidence is central to critical thinking. By providing students with opportunities to analyze data and draw conclusions, the STEM-based guided inquiry model helped them strengthen these skills.

Moreover, the model's focus on reflection further contributed to the development of critical thinking skills. Reflection allows students to evaluate their thought processes, recognize biases, and refine their reasoning. Lalumia (2021) emphasized the importance of reflection in critical thinking, as it enables students to assess and refine their thinking. By encouraging students to reflect on their learning experiences, the STEM-based model provided them with opportunities to improve their critical thinking abilities.

4. CONCLUSION

The findings of this study confirm that the STEM-based guided inquiry learning model significantly enhances students' critical thinking skills. The statistical analysis, including both independent-sample and paired-sample t-tests, revealed significant improvements in the experimental group's performance, supporting the hypothesis that this model is effective in fostering critical thinking. The interdisciplinary nature of STEM, combined with the active, inquiry-based approach of the guided inquiry model, provided students with a rich learning environment that facilitated the development of essential critical thinking skills. By integrating real-world problems, encouraging active learning, and providing opportunities for reflection, the STEM-based guided inquiry model effectively supported students in becoming more critical and analytical thinkers. These results suggest that the integration of STEM disciplines through guided inquiry can play a vital role in enhancing critical thinking skills, preparing students for the challenges of the modern world.

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6. REFERENCES

Çalik, M., & Kurt, S. (2024). The Effect of Interventions Teaching Chemical Kinetics on Students' Academic Performance: A Meta-Analysis Study. International Journal of Science and Mathematics Education. https://doi.org/10.1007/s10763-024-10523-w

Dewi, E., Ratman, R., & Mustapa, K. (2020). The implementation of guided inquiry learning model to enhance students' critical thinking skills on reaction rate topic: the case of an Indonesian public school. J-PEK (Jurnal Pembelajaran Kimia), 5(2). https://doi.org/10.17977/um026v5i22020p066

Facione, P. A. (2015). Critical Thinking: What It Is and Why It Counts. Insight Assessment. Insight Assessment, 5(1).

Fadhilah, F., Jusniar, J., & Anwar, M. (2020). Analisis Miskonsepsi Siswa Kelas XI IPA 1 SMA Negeri 1 Ma'rang Pada Materi Pokok Laju Reaksi. ChemEdu, 1(1). https://doi.org/10.35580/chemedu.v1i1.17526

Ghaemi, F., & Mirsaeed, S. J. G. (2017). The Impact of Inquiry-based Learning approach on Critical Thinking Skill of EFL Students. EFL JOURNAL, 2(2). https://doi.org/10.21462/eflj.v2i2.38

Herunata, H. (2025). The Effectiveness of Guided Inquiry Learning Based on Anderson's Sketch Analysis on Students' Higher Order Thinking Skills in Reaction Rate. Ecletica Quimica, 50. https://doi.org/10.26850/1678-4618.eq.v50.2025.e1573

Hmelo-Silver, C. E. (2004). Problem-based learning: What and how do students learn? In Educational Psychology Review (Vol. 16, Number 3). https://doi.org/10.1023/B:EDPR.0000034022.16470.f3

Johnstone, A. H. (2006). Chemical education research in Glasgow in perspective. In Chemistry Education Research and Practice (Vol. 7, Number 2). https://doi.org/10.1039/B5RP90021B

Jusniar, J., Effendy, E., Budiasih, E., & Sutrisno, S. (2020). Misconceptions in rate of reaction and their impact on misconceptions in chemical equilibrium. European Journal of Educational Research, 9(4). https://doi.org/10.12973/eu-jer.9.4.1405

LaLumia, J. (2021). HOW WE THINK. In The Ways of Reason. https://doi.org/10.4324/9781315830483-9

Michael Prince. (2004). Does Active Learning Work ? A Review of the Research. Journal of Engineering Education, 93(July).

Pohan, L. A., Suyanti, R. D., Nugraha, A. W., Pebrianti, D., Panjaitan, R., & Hasibuan, S. H. (2024). Jurnal Pendidikan IPA Indonesia Implementation Of Stem-Based Inquiry In Learning Fundamental Laws Of Chemistry: Students' Perception And Response. JPII, 13(3), 447–458. https://doi.org/10.15294/jpii.v13i3.3431

Rahmawati, Y., Zulhipri, Hartanto, O., Falani, I., & Iriyadi, D. (2022). Students' Conceptual Understanding In Chemistry Learning Using Phet Interactive Simulations. Journal of Technology and Science Education, 12(2). https://doi.org/10.3926/jotse.1597

Sue Z.Beers. (2014). 21st Century Skills: Preparing Students for THEIR Future. Gigiena i Sanitariia, 93(6).

Sulastri, Rasul, M. S., Juliana, Syahrial, & Zatya, I. (2025). Stem-Based Guided Inquiry In Colloid Practicums And Its Influence On Students' Concept Mastery. Jurnal Pendidikan IPA Indonesia, 14(2), 296–303. https://doi.org/10.15294/jpii.v14i2.23967

Winarni, S., Effendy, E., Budiasih, E., & Wonorahardjo, S. (2022). Constructing "Concept Approval Strategy," A Chemistry Learning Idea to Prevent Misconceptions. Educacion Quimica, 33(2). https://doi.org/10.22201/fq.18708404e.2022.2.79841