Electronic Journal of Education, Social Economics and Technology
Vol. 7, No. 1, (2026), e1513
ISSN 2723-6250 (online)
DOI: https://doi.org/10.33122/ejeset.v7i1.1513

Research Article

The Impact of Guided Inquiry Learning on Students' Conceptual Understanding of Colloid System

Mawardaniati, Isna Rezkia Lukman*, Ratna Unaida, Ayu Rahmi, Riska Imanda

Faculty of Teachers Training and Education, Universitas Malikussaleh, Aceh Utara, 24351, Indonesia

*Corresponding Author: rezkia.lukman@unimal.ac.id | Phone: +6281220237241

ABSTRACT

Mastering abstract chemistry concepts such as the colloid system requires effective instructional strategies that promote active knowledge construction. This study aimed to investigate the impact of the guided inquiry learning model on students' conceptual understanding of colloid systems. A quantitative pre-experimental approach with an intact-group comparison design was employed. Utilizing purposive sampling, 47 eleventh-grade students from an Islamic Senior High School in Indonesia were selected and divided into an experimental group (n=27) taught using guided inquiry and a control group (n=20) taught using conventional teacher-centered methods. Data were collected using a validated two-tier multiple-choice diagnostic post-test to evaluate conceptual mastery and uncover underlying misconceptions. The independent sample t-test analysis revealed a statistically significant difference ($p = 0.000 < 0.05$) between the two groups. The experimental group achieved a higher average score (74.41, High category) compared to the control group (58.86, Moderate category). Furthermore, the diagnostic test demonstrated that guided inquiry substantially increased true conceptual understanding and effectively minimized the rates of student misconceptions and complete lack of understanding. The findings conclude that guided inquiry is a highly effective instructional model for enhancing meaningful learning in chemistry, assisting students in connecting macroscopic observations with theoretical concepts, although further scaffolding is needed for submicroscopic particle-level mechanisms.

Keywords: Colloid System; Conceptual Understanding; Guided Inquiry; Two-Tier Multiple Choice.

1. INTRODUCTION

Modern education emphasizes the importance of student-centered learning to help students build meaningful knowledge rather than merely memorizing information provided by teachers (Amini et al., 2023; Ahmad Dhomiri et al., 2023). In science education, particularly chemistry, achieving deep conceptual understanding is essential. Chemistry plays a crucial role in developing logical, analytical, and systematic thinking skills. However, it is often perceived as a difficult and abstract subject by many students because its core concepts lie at the microscopic level, which cannot be observed directly and requires high reasoning skills to comprehend (Ariani et al., 2024). Consequently, fostering robust conceptual understanding remains a primary concern in chemistry learning.

One specific chemistry topic that frequently causes comprehension difficulties for students is the colloid system. The colloid material requires students to understand dispersion systems, particle sizes, classifications, and properties (e.g., Tyndall effect, Brownian motion, adsorption), as well as their applications in daily life. The characteristics of this topic are highly contextual yet abstract. Students must connect macroscopic observations with microscopic processes. The inability to accurately link macroscopic, sub-microscopic, and symbolic representations often leads to misconceptions and poor conceptual understanding (Rahmawati et al., 2025;Zahro et al., 2024). This highlights the need for an instructional strategy that assists students in meaningfully constructing relationships between concepts and multiple representations (Sihaloho et al., 2025).

The complexity of the colloid system demands a learning environment that transcends rote memorization and passive reception. Grounded in constructivist theory, meaningful learning occurs when students actively integrate new information with their prior knowledge to build coherent cognitive structures (Asrifan et al., 2025; Sharan, 2015; Sharma & Chawla, 2019). However, conventional instruction often bypasses this critical construction phase, presenting colloid phenomena merely as facts to be memorized rather than mechanisms to be explored. This superficial approach exacerbates students' cognitive load, particularly when they are required to transition seamlessly between macroscopic observations, submicroscopic particle interactions, and symbolic representations(Carlson et al., 2003; Thompson & Lake, 2023; Wu et al., 2022). Consequently, without proper instructional scaffolding, students struggle to visualize the dynamic nature of colloidal dispersions, leading to deeply rooted misconceptions that hinder their overall scientific literacy (Azevedo et al., 2004; Jumaat

& Tasir, 2014; Miterianifa et al., 2020).

Conceptual understanding is defined as the students' ability to logically interpret, explain, and interrelate concepts to prevent misconceptions (Fathonah et al., 2024). Good conceptual understanding is reflected in the ability to apply concepts flexibly, efficiently, and accurately to scientific phenomena (Yeni et al., 2024). Poor conceptual understanding often occurs when the learning process emphasizes rote memorization over knowledge construction. Therefore, assessing conceptual understanding requires more than standard multiple-choice tests, which only evaluate the final answer. The Two-Tier Multiple Choice diagnostic instrument is highly effective for this purpose, as its first tier assesses the student's factual choice, while the second tier evaluates the underlying scientific reasoning, successfully uncovering hidden misconceptions (Ananda & Suharto, 2021 ; Azizah et al., 2022)

Despite the demand for meaningful learning, preliminary observations and interviews at a high school (Madrasah Aliyah Jabal Nur) revealed a prevalent reliance on conventional, teacher-centered methods. The dominance of lecturing makes students passive recipients of information, limiting their opportunities to explore and independently construct knowledge (Suryadinata, 2025). This condition aligns with the general characteristic of chemistry being considered difficult (Astafani et al., 2024), resulting in students failing to meet the minimum mastery criteria. There is a critical need for an effective learning model that stimulates thinking skills and provides direct learning experiences to clarify abstract concepts (Umar et al., 2022).

To address this gap, Guided Inquiry Learning emerges as a highly relevant instructional model. This model engages students actively in scientific investigations under the teacher's guidance as a facilitator (Rodri et al., 2025). By observing phenomena, identifying problems, formulating hypotheses, collecting and analyzing data, and drawing conclusions, students are given the opportunity to build their own understanding based on empirical evidence. Previous studies have demonstrated that guided inquiry significantly enhances students' conceptual understanding and reduces misconceptions (Fuad & Wildani, 2025; Saija & Beay, 2022) Furthermore, recent research specifically indicates the positive effect of inquiry-based approaches on mastering colloid concepts (Sulastri et al., 2025)

To further bridge the gap between abstract chemical concepts and students' cognitive capacities, the Guided Inquiry Learning model offers a highly structured yet autonomous pedagogical framework. While open inquiry might overwhelm students due to a lack of structure, guided inquiry provides essential teacher scaffolding systematically, ensuring that students do not deviate from the core scientific principles (Aragües, 2023; Loertscher & Minderhout, 2019; Vroom Redden et al., 2020). Recent comprehensive reviews assert that incorporating small-scale experiments and guided investigations significantly enhances science process skills, multiple representation mastery, and conceptual retention, making it an ideal strategy for intricate topics like chemistry (Hunnicutt et al., 2015; Maison et al., 2020; Tornee et al., 2019)

However, accurately measuring the impact of such instructional interventions remains a persistent challenge in science education research. Traditional assessment methods often fail to distinguish between true conceptual mastery, guessing, and ingrained misconceptions(Fakiyesi et al., 2025; Jiang et al., 2025; Nurrizqi et al., 2025). The integration of the Two-Tier Multiple Choice diagnostic instrument is imperative to address this methodological gap. By requiring students to articulate their scientific justification, this instrument provides a multidimensional map of students' understanding(Bråten et al., 2013; Zazkis & Rouhani, 2024). This diagnostic capability reveals exactly where the instructional scaffolding of guided inquiry succeeds and where submicroscopic conceptual blockages persist.

While previous studies have independently explored the benefits of guided inquiry or the utility of two-tier diagnostics, there is a distinct scarcity of research that integrates both to deeply evaluate the mastery of the colloid system, particularly within the context of an Islamic Senior High School in Indonesia. This demographic often experiences unique pedagogical dynamics where the transition to student-centered learning is challenging yet profoundly necessary(Armellini et al., 2021; Manning et al., 2023; Shaw et al., 2019). This study is uniquely positioned to fill this specific research gap. By synergizing the guided inquiry learning model with a rigorous two-tier diagnostic evaluation, this research aims not only to quantify the improvement in conceptual understanding but also to qualitatively map how guided scaffolding dismantles specific chemical misconceptions.

Based on the existing gap between the ideal chemistry instruction and the reality of passive classroom practices, this study aims to investigate the impact of the guided inquiry learning model on students' conceptual understanding of the colloid system. By utilizing a two-tier multiple-choice assessment, this research seeks to provide comprehensive insights into how guided inquiry influences students' ability to construct scientifically accurate concepts.

2. RESEARCH METHOD

2.1 Research Design

This study employed a quantitative approach using a pre-experimental intact-group comparison design (Waruwu et al., 2025). The research involved two existing (intact) classes functioning as different groups: an experimental group that received the treatment using the guided inquiry learning model, and a control group taught using a conventional, teacher-centered instructional model. A post-test was administered to both groups at the end of the learning period to measure and compare the impact of the respective treatments on the students' conceptual understanding of colloid systems.

2.2 Participants

The research was conducted at an Islamic Senior High School (Madrasah Aliyah Jabal Nur) in North Aceh, Indonesia, during the even semester of the academic year. The population comprised all eleventh-grade students across four classes. Using a purposive sampling technique, two classes were selected as the research sample based on the equivalence of their prior academic performance and teacher recommendations. Class XI-1, consisting of 27 students, was assigned as the experimental group, while Class XI-4, consisting of 20 students, served as the control group

2.3 Data Collection Instrument

Data were collected using a diagnostic two-tier multiple-choice test focused on the colloid system. The test was administered as a post-test to evaluate the students' conceptual understanding. The first tier of the instrument assesses the students' factual knowledge by asking them to select the correct answer, while the second tier requires them to choose the underlying scientific reasoning for their answer in the first tier.

2.4 Data Processing Technique

The students' responses were evaluated based on a specific scoring rubric adapted from Fajri et al., (2022). A score of 1 is awarded only if both the answer and the reason are correct, while other combinations receive a score of 0, as detailed in **Table 1.**

Table 1. Category and Scoring Rubric for the Two-Tier Multiple Choice Instrument

Category	Criteria	Score
Lack of Understanding	Incorrect answer and incorrect/blank reason	0
Guessing	Incorrect answer but correct reason	0
Misconception	Correct answer but incorrect reason	0
Conceptual Understanding	Correct answer and correct reason	1

Source: Adapted from (Fajri et al., 2022)

The final conceptual understanding score was calculated as a percentage by dividing the total score obtained by the maximum possible score, multiplied by 100%. The resulting percentages were then classified into five descriptive categories of conceptual understanding based on the criteria established by Musa et al., (2023), as presented in **Table 2.**

Table 2. Criteria for Students' Conceptual Understanding Scores

Percentage (%)	Category
80 – 100	Very High
61 – 80	High
41 – 60	Moderate
21 – 40	Low
0 – 20	Very Low

Source: Adapted from (Fajri et al., 2022)

Furthermore, to map the students' cognitive structures, the data were processed item-by-item to calculate the percentage distribution of students falling into each diagnostic category (Conceptual Understanding, Misconception, Guessing, and Lack of Understanding). This specific processing technique allowed researchers to identify exactly which sub-topics of the colloid system harbored the highest misconception rates.

2.5 Data Analysis

Prior to the primary data collection, the research instrument underwent empirical feasibility tests, encompassing validity (using Pearson correlation), reliability (using Cronbach's alpha), difficulty index, and discrimination power analyses. The primary data analysis was conducted using descriptive and inferential statistics facilitated by statistical software (IBM SPSS Statistics). Descriptive statistics were used to determine the mean scores and the frequency distributions of the conceptual categories. For inferential statistics, prerequisite tests were mandatory before conducting hypothesis testing. The Shapiro-Wilk test was utilized to evaluate data normality, which is highly appropriate for sample sizes of less than 50 ($n < 50$). Subsequently, Levene's test was conducted to assess the homogeneity of variances between the experimental and control groups. Finally, to test the research hypothesis and determine the significance of the instructional impact, an Independent Sample t-test was employed. In cases where the variances were not homogeneous based on Levene's test, the *equal variances not assumed* (Welch's t-test) condition was applied. The statistical decision was based on a significance level of $\alpha = 0.05$. The null hypothesis (H_0) is rejected if the *p-value* (Sig. 2-tailed) is less than 0.05, establishing that the guided inquiry learning model significantly impacts students' conceptual understanding compared to conventional methods.

3. RESULTS AND DISCUSSION

3.1 *Prerequisite Analysis and Hypothesis Testing*

Prior to evaluating the impact of the instructional model, prerequisite analyses comprising normality and homogeneity tests were conducted on the post-test data. The Shapiro-Wilk test was utilized to assess data normality. As presented in Table 3, the results indicated that the post-test data for both the experimental group ($p = 0.118$) and the control group ($p = 0.380$) were normally distributed, as the significance values exceeded the $\alpha = 0.05$ threshold.

Table 3. Normality Test Results of Conceptual Understanding

.

Class	Shapiro wilk		
	Statistic	df	Sig.
Experimental	.939	27	.118
Control	.951	20	.380

Furthermore, the Levene's test for equality of variances was conducted to determine the homogeneity of the data. As shown in **Table 4**, the test yielded a significance value of $p = 0.010$ ($p < 0.05$), indicating that the data variances between the two groups were not homogeneous.

Table 4. Homogeneity Test Results

Levene Statistic	df1	df2	Sig.
7.252	1	45	.010

Consequently, to test the research hypothesis, an Independent Sample t-test with the *equal variances not assumed* condition was employed. The statistical analysis (**Table 5**) revealed a Sig. (2-tailed) value of 0.000 ($p < 0.05$).

Table 5. Independent Sample t-test Results

Variable	Assumed Variance	df	Sig. (2-tailed)
Conceptual Understanding	Equal variances not assumed	45	0.000

This results leads to the rejection of the null hypothesis (H_0) and the acceptance of the alternative hypothesis (H_1). It can be conclusively stated that the implementation of the guided inquiry learning model significantly impacts students' conceptual understanding of the colloid system compared to conventional teaching methods. This statistical finding is consistent with previous studies which assert that guided inquiry learning models effectively enhance students' conceptual understanding across various chemistry topics, including buffer solutions and thermochemistry (Leonarda et al., 2023) ; Sulistiyono, 2020).

3.2 *Analysis of Students' Conceptual Understanding*

The significant impact identified in the hypothesis testing is further reflected in the descriptive comparison of the students' post-test scores. As illustrated in **Figure 1**, the experimental group, which engaged in guided inquiry learning, achieved a higher average conceptual understanding score of 74.41 (categorized as *High*). In contrast, the control group recorded a lower average score of 58.86 (categorized as *Moderate*).

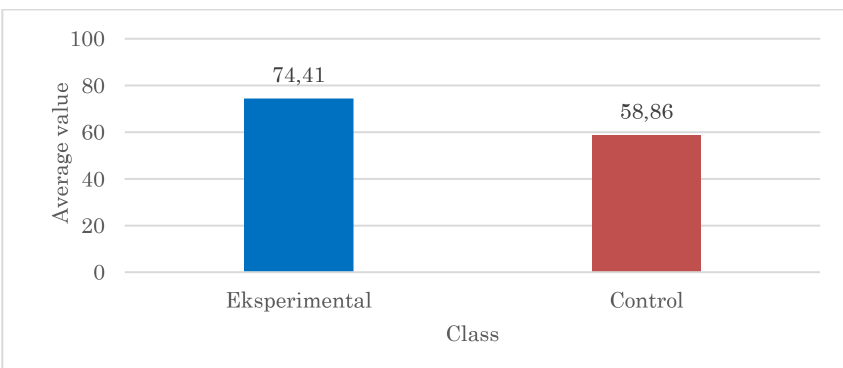
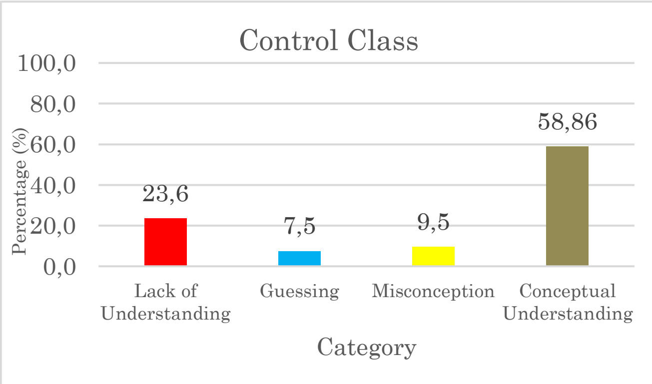


Figure 1. Average Post-test Scores of Conceptual Understanding

The use of the Two-Tier Multiple Choice diagnostic instrument provided deeper insights into the students' cognitive structures, successfully identifying true conceptual understanding, misconceptions, and lack of understanding through both the answers and the underlying reasoning(Seng & Lian, 2026). The percentage distribution of these conceptual categories for both classes is visualized in **Figure 2**.



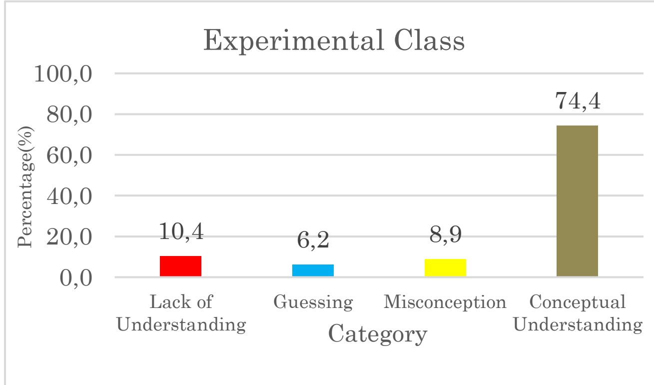


Figure 2. Percentage of Conceptual Understanding

Based on the figures above, the analysis demonstrated that the experimental group outperformed the control group significantly in the *Conceptual Understanding (PK)* category, achieving 74.4% compared to the control group's 58.9%. Furthermore, the *Lack of Understanding (TPK)* category was substantially minimized in the experimental group (10.4%) compared to the control group (23.6%). The rates of misconceptions and guessing were also noticeably lower in the experimental class. This evidence corroborates the notion that guided inquiry learning not only elevates comprehension but also effectively mitigates student ignorance and misconceptions (Latukau, 2022).

3.3 Discussion on Specific Colloid Concepts and Misconceptions

An item-by-item analysis of the diagnostic test revealed varying levels of comprehension among the students, illuminating specific cognitive strengths and barriers in learning the colloid system. The highest level of conceptual understanding was observed in item number 1 (92.6%), which assessed the classification of aerosols and emulsions. This exceptionally high mastery indicates that students are highly capable of connecting theoretical concepts with observable, everyday macroscopic phenomena, such as fog or milk. Because these concepts are deeply rooted in their daily experiences, students can easily assimilate the new information into their existing cognitive structures (Mellyzar et al., 2022). Conversely, the lowest comprehension rates were found in items 4 and 21 (44.4%), which dealt with the preparation methods and complex classifications of colloids. This stark contrast highlights the students' ongoing difficulties in linking theoretical concepts with the dynamic mechanisms of colloid formation. Preparation methods (such as dispersion and condensation) require students to visualize invisible particle aggregations or breakdowns. The struggle evident in these items underlines the well-documented cognitive bottleneck that occurs when students are forced to transition simultaneously between macroscopic observations, submicroscopic particle-level interactions, and symbolic chemical equations without adequate visualization aids (Wang et al., 2022).

The utilization of the two-tier multiple-choice instrument proved crucial in unmasking the "illusion of competence" often found in traditional assessments. Regarding misconceptions, the highest occurrence in the experimental group was found in item 4 (40.7%), while the control group struggled most with item 13 (30.0%). These findings indicate a critical phenomenon: while many students can successfully memorize or guess the correct factual answer in the first tier, they often lack the appropriate scientific reasoning to justify it in the second tier. In a conventional multiple-choice test, these students would be misclassified as having understood the concept, masking their fragmented cognitive schemas (Ananda & Suharto, 2021 ; Fajri et al., 2022). By exposing these hidden misconceptions, the study demonstrates that rote learning strategies, prevalent in the control group, fail to build coherent logical frameworks necessary for robust scientific reasoning.

Furthermore, the data regarding students' Lack of Understanding (TPK) provides profound insights into the limitations of current instructional practices. The highest rate of TPK was recorded in item 22 (gel preparation via solvent replacement), affecting a staggering 85.0% of the control group. While the guided inquiry intervention significantly reduced this ignorance rate to 48.1% in the experimental group, the figure remains relatively high. This condition suggests that highly abstract concepts involving particle-level mechanisms remain profoundly challenging to grasp solely through macroscopic laboratory activities. Solvent replacement mechanisms require students to mentally model the kinetic behavior of molecules and their physical interactions. Without explicit submicroscopic representation and targeted instructional scaffolding, such as molecular animations or digital simulations, students' mental models remain incomplete or severely distorted (Keiner & Graulich, 2021;Morais et al., 2024;Locatelli, 2021).

Overall, despite the persistent challenges at the submicroscopic level, the guided inquiry model demonstrably facilitated significantly better conceptual understanding than the conventional approach. By actively involving students in observing phenomena, formulating hypotheses, investigating empirical data, and drawing scientifically sound conclusions, the model forces students to actively confront and correct their prior misconceptions. This instructional approach aligns seamlessly with constructivism theory, which posits that meaningful learning is not passive absorption but an active process of cognitive accommodation and (Blown, 2024 ; Jr & Adlaon, 2026; Winarni et al., 2022). When students discover the principles of the Tyndall effect or coagulation through guided empirical investigation, the knowledge constructed is far more durable and logically interconnected.

The findings of this study contribute significant empirical evidence to the existing body of literature, strongly supporting the premise that guided inquiry learning significantly improves conceptual mastery. The structured nature of the "guided" inquiry ensures that students are not cognitively overwhelmed as they might be in open inquiry while still maintaining the autonomy necessary for deep cognitive reflection and evidence-based analysis (Pahriah et al., 2024;, Karal Eyüboğlu & Sağlam Arslan, 2024;, Zahronada et al., 2025). The pedagogical implication of this research is clear: to foster true chemical literacy and eradicate persistent misconceptions in topics like the colloid system, educators must transition from lecture-based delivery to inquiry-based scaffolding, whilst concurrently integrating technological visualization tools to bridge the persistent gap between macroscopic experiments and submicroscopic realities.

4. CONCLUSION

Based on the findings and data analysis, it can be concluded that the implementation of the guided inquiry learning model has a significant and positive impact on students' conceptual understanding of the colloid system. The statistical evidence confirms that students engaged in guided inquiry significantly outperformed those taught using conventional, teacher-centered methods. Beyond the statistical significance, the use of the two-tier multiple-choice diagnostic test revealed that guided inquiry not only enhances true conceptual mastery but also effectively minimizes the rates of student misconceptions and complete lack of understanding (ignorance). By actively involving students in the scientific investigation process, the model successfully shifts the learning paradigm from passive rote memorization to active knowledge construction, helping students connect abstract theoretical concepts with observable macroscopic phenomena. However, despite the overall improvement, this study also highlights a specific limitation: students still encounter difficulties in comprehending complex mechanisms at the submicroscopic level, such as particle interactions during colloid preparation (e.g., gel formation). Therefore, the findings of this study imply that chemistry educators should adopt guided inquiry as a highly effective instructional strategy to foster meaningful learning. For future research, it is strongly recommended to integrate the guided inquiry model with immersive visual technologies or digital simulations. Providing explicit scaffolding for submicroscopic and symbolic representations will further assist students in visualizing particle-level mechanisms and completely eradicating lingering chemistry misconceptions.

ACKNOWLEDGEMENTS

The authors would like to express their sincere gratitude to the principal, chemistry teachers, and all eleventh-grade students of Madrasah Aliyah Jabal Nur for their invaluable participation, cooperation, and enthusiasm during the data collection process. We also extend our deepest appreciation to the Chemistry Education Study Program, Universitas Malikussaleh, for providing the necessary academic support and facilities that made this research possible.

REFERENCES

Ahmad Dhomiri, Junedi Junedi, & Mukh Nursikin. (2023). Konsep Dasar dan Peranan serta Fungsi Kurikulum dalam Pendidikan. Khatulistiwa: Jurnal Pendidikan Dan Sosial Humaniora, 3(1), 118–128. https://doi.org/10.55606/khatulistiwa.v3i1.972

Amini, A., Putra, H., Putri Siregar, C. Z., Fatahillah, M., Zulviannas, R., & Hasibuan, M. (2023). Peran Pendidikan Dalam Membangun Karakter Bangsa Indonesia. Mimbar Kampus: Jurnal Pendidikan Dan Agama Islam, 23(1), 38–43. https://doi.org/10.47467/mk.v23i1.3264

Ananda, L. rizkyta, & Suharto, H. (2021). Penggunaan Two-Tier Multiple Choice Diagnostik Test untuk mengidentifikasi Miskonsepsi Siswa Kelas X SMAN 1 Tangerang Selatan pada Materi Larutan Elektrolit dan Non Elektrolit. Jurnal Riset Pendidikan Kimia, 11(2), 82–88. https://doi.org/10.21009/JRPK.112.04

Aragües, A. M. (2023). Constructing Scientific Knowledge through the Teacher´s Questions in a Guided-Inquiry Primary Lesson of the Water Cycle. Acta Scientiae, 25(4), 256–283. https://doi.org/10.17648/ACTA.SCIENTIAE.6082

Ariani, Z., Rizaldi, R. D., Fahrurrozi, M., Ratnasari, D. B., & Fatimah, Z. (2024). Analisis Faktor-Faktor Penyebab Kesulitan Belajar Siswa Pada Pelajaran Kimia Materi Senyawa Hidrokarbon di MA Plus Nurul Islam Sekarbela. Action Research Journal (ARJ), 1(3), 216–224.

Armellini, A., Teixeira Antunes, V., & Howe, R. (2021). Student Perspectives on Learning Experiences in a Higher Education Active Blended Learning Context. TechTrends, 65(4), 433–443. https://doi.org/10.1007/S11528-021-00593-W

Asrifan, A., Octaberliana, L. R. O. R., Nursyam, N., Sudiati, R. S., Tasni, N., & Pajarianto, H. (2025). Constructivism and robotics: Building bridges in learning theories and educational practice. Innovations in Educational Robotics:

Advancing AI for Sustainable Development, 39–68. https://doi.org/10.4018/979-8-3693-6165-8.CH003

Azevedo, R., Cromley, J. G., & Seibert, D. (2004). Does adaptive scaffolding facilitate students' ability to regulate their learning with hypermedia? Contemporary Educational Psychology, 29(3), 344–370. https://doi.org/10.1016/J.CEDPSYCH.2003.09.002

Azizah, N. L., Mahardiani, L., & Yamtinah, S. (2022). Analisis Miskonsepsi Dengan Tes Diagnostik Two-Tier Multiple Choice Dan In-Depth Interview Pada Materi Asam Basa. Jurnal Pendiidikan Kimia, 11(2), 168–177. https://doi.org/10.20961/jpkim.v11i2.60345

Blown, T. G. K. B. E. J. (2024). Ausubel ' s meaningful learning re-visited. Current Psychology, (April 2023), 4579–4598. https://doi.org/DOI: 10.1007/s12144-023-04440-4

Bråten, I., Ferguson, L. E., Strømsø, H. I., & Anmarkrud, Ø. (2013). Justification beliefs and multiple-documents comprehension. European Journal of Psychology of Education, 28(3), 879–902. https://doi.org/10.1007/S10212-012-0145-2

Carlson, R., Chandler, P., & Sweller, J. (2003). Learning and Understanding Science Instructional Material. Journal of Educational Psychology, 95(3), 629–640. https://doi.org/10.1037/0022-0663.95.3.629

Fajri, A., Roviati, E., & Anugrah, I. rizki. (2022). Identifikasi Miskonsepsi Siswa Dengan Two Tier Diagnostic test Pada Materi Hereditas. Jurnal Pendidikan Teori Dan Praktik, 6(2), 116–123. https://doi.org/10.63987/arj.v1i3.147

Fakiyesi, V., Moyaki, D., Feyijimi, T. R., & Hunsu, N. (2025). WIP: Analyzing Students' Reasoning Patterns in Electric Circuit Misconceptions: A Thematic Approach. Proceedings-Frontiers in Education Conference, FIE. https://doi.org/10.1109/FIE63693.2025.11328299

Fathonah, E., Hidayati, A., Saputra, S., & Suhaela, H. (2024). Literature Review: Pemahaman Konsep Siswa dalam Pembelajaran Kimia. Arfak Chem: Chemistry Education Journal, 7(1), 581–586. https://doi.org/10.30862/accej.v7i1.598

Fuad, M. F., & Wildani, A. (2025). Pengaruh Model Pembelajaran Inkuiri Terbimbing Berbantuan Augmented Reality Terhadap Peningkatan Pemahaman Konsep dan Minat Belajar Peserta Didik pada Materi Cermin Cembung. Jurnal Pengabdian Masyarakat Dan Riset Pendidikan, 4(2), 10819–10826. https://doi.org/10.31004/jerkin.v4i2.3567 ARTICLE

Hunnicutt, S. S., Grushow, A., & Whitnell, R. (2015). Guided-inquiry experiments for physical chemistry: The POGIL-PCL model. Journal of Chemical Education, 92(2), 262–268. https://doi.org/10.1021/ED5003916

Jiang, Z., Wu, J., & Jiang, N. (2025). Overcoming Illusionary Difficulty in Novice Programming through Metacognitive Skill Enhancement. SIGCSE TS 2025 - Proceedings of the 56th ACM Technical Symposium on Computer Science Education, 2, 1497–1498. https://doi.org/10.1145/3641555.3705230

Jr, C. B. A., & Adlaon, M. S. (2026). Constructivist Teaching Strategies in Secondary Science Education : A Systematic Review of Student- Centered and Active Learning Approaches. Jurnal Acta Pedagogia Asiana, 5(2), 346–364. https://doi.org/10.53623/apga.v5i2.1141

Jumaat, N. F., & Tasir, Z. (2014). Instructional scaffolding in online learning environment: A meta-analysis. Proceedings - 2014 International Conference on Teaching and Learning in Computing and Engineering, LATICE 2014, 74–77. https://doi.org/10.1109/LATICE.2014.22

Karal Eyüboğlu, I. S., & Sağlam Arslan, A. (2024). Effectiveness of Guided Inquiry Based Laboratory Instruction on Prospective Science Teachers ' Procedural and Conceptual Understandings. Educational Academic Research, 54, 89–104. https://doi.org/10.33418/education.1458760

Keiner, L., & Graulich, N. (2021). Research and Practice Beyond the beaker : students ' use of a scaffold to organic chemistry laboratory. Chemistry Education Research and Practice, 22, 146–163. https://doi.org/10.1039/D0RP00206B

Latukau, M. (2022). Pembelajaran IPA Dengan Model Inkuiri Terbimbing Untuk Meningkatkan Pemahaman Konsep dan Keterampilan Proses Sains Siswa SD Munir Latukau Dosen Program Studi PGSD STKIP Kie Raha Ternate. Jurnal Ilmiah Wahana Pendidikan, 8(23), 351–362. https://doi.org/10.5281/zenodo.7397601

Leonarda, Y., Hokeng, S., Leto, K. T., & Nisa, K. R. (2023). The Effect of Guided Inquiry Learning Model on the Students ' Conceptual Understanding in SMA Negeri 1 Talibura. Dalton : Jurnal Pendidikan Kimia Dan Ilmu Kimia, 5(2), 86–93. https://doi.org/10.31602/dl.v5i2.7909

Locatelli, S. W. (2021). Research and Practice Using metavisualization to revise an explanatory model regarding a chemical reaction. Chemistry Education Research and Practice, 22(January), 382–395. https://doi.org/10.1039/D0RP00339E

Loertscher, J., & Minderhout, V. (2019). Implementing Guided Inquiry in Biochemistry: Challenges and Opportunities. ACS Symposium Series, 1337, 111–126. https://doi.org/10.1021/BK-2019-1337.CH005

Maison, Darmaji, Aatalini, Kurniawan, D. A., Haryanto, Kurniawan, W., Suryani, A., Lumbantoruan, A., & Dewi, U. P. (2020). Science process skill in science program higher education. Universal Journal of Educational Research, 8(2), 652–661. https://doi.org/10.13189/UJER.2020.080238

Manning, L., Murray, F., Lang, E. H., Munsey, B., & Wigington, T. (2023). Learning experiences within helping disciplines: Faculty and student observations. Journal of Pedagogical Sociology and Psychology, 5(1), 31–43. https://doi.org/10.33902/JPSP.202315517

Mellyzar, Lukman, I. R., Alvina, S., Pasaribu, A. I., & Fadli, M. R. (2022). Chemical Literacy of High School Students : Analysis of Cognitive Abilities on Colloid Material. Jurnal Penelitian Pendidikan IPA, 8(6), 3128–3133. https://doi.org/10.29303/jppipa.v8i6.2377

Miterianifa, Ashadi, Saputro, S., & Suciati. (2020). Analysis of errors and scaffolding in problem-solving processes on colloid topic for class XI senior high school. AIP Conference Proceedings, 2296. https://doi.org/10.1063/5.0030457

Morais, C., Rae, A., & Doolittle, P. S. (2024). Research and Practice Supporting submicroscopic reasoning in students '. Chemistry Education Research and Practice, 25(October 2023), 133–150. https://doi.org/10.1039/D3RP00153A

Musa, W. J. A., Mantuli, M. A., Tangio, J. S., Iyabu, H., La killo, J., & Kadir killo, A. (2023). Identifikasi Pemahaman Konsep Tingkat Representasi Makroskopik , Mikroskopik , dan Simbolik pada Materi Ikatan Kimia. Jambura Journal of Educational Chemistry, 5(1), 52–59. https://doi.org/10.34312/jjec.v5i1.15201

Nurrizqi, A. E. F., Mahardiani, L., Probosari, R. M., Indriyanti, N. Y., Hudha, M. N., & Gunawan, K. D. H. (2025). Mapping the Architecture of Misconceptions: Network Analysis and Confidence Calibration in Three-Tier Diagnostic Assessment with Implications for Targeted Instruction. European Journal of Social Science Education and Research, 12(4), 285–314. https://doi.org/10.26417/DWR70028

Pahriah, Adnyana, P. B., Ariawan, I. putu wisna, & Wesnawa, I. G. A. (2024). Effectiveness of the Constructivist Approach (Guided Inquiry) in Chemistry Learning: A Systematic Review. Hydrogen: Jurnal Kependidikan Kimia, 12(15), 1152–1165. https://doi.org/https://doi.org/10.33394/hjkk.v12i5.13353 https://doi.org/10.33394/hjkk.v12i5.13353

Rahmawati, R., Subarkah, C. Z., Sukmawardani, Y., Sarjana, P., & Barat, J. (2025). Pengaruh Pembelajaran Berbasis Multiple Representation Untuk Meningkatkan Pemahaman Konsep Kimia Pada Materi Laju Reaksi. Eduproxima: Jurnal Ilmiah Pendidikan IPA, 7(3), 1110–1117. https://doi.org/10.29100/.v7i3.7380

Rodri, N. Z., Arrahman, A., Fitrah, H., & Novalita, R. (2025). Penerapan Model Pembelajaran Inkuiri Terbimbing untuk Meningkatkan Hasil Belajar. Jurnal Pengabdian Masyarakat Dan Riset Pendidikan, 4(1), 2730–2739. https://doi.org/10.31004/jerkin.v4i1.2051

Saija, M., & Beay, K. lazarus. (2022). LKM Berbasis Inkuiri Terbimbing Untuk Meningkatkan Pemahaman Konseptual dan Motivasi Belajar Kimia. 4(1), 1–7. https://doi.org/10.34312/jjec.v4i1.13492

Seng, K. W., & Lian, L. H. (2026). (Development of a Two-Tier Cognitive Diagnostic Test to Identify Misconceptions of Basic Operations of Algebraic Expression). Malaysian Journal of Learning and Instruction, 23(1), 181–204. https://doi.org/10.32890/MJLI2026.23.1.9

Sharan, Y. (2015). Meaningful learning in the cooperative classroom. Education 3-13, 43(1), 83–94. https://doi.org/10.1080/03004279.2015.961723

Sharma, M., & Chawla, S. (2019). Using a Concept Map Network Based Constructivist Learning Environment to Design a Learning System. Communications in Computer and Information Science, 835, 56–69. https://doi.org/10.1007/978-981-13-5992-7_5

Shaw, T. J., Yang, S., Nash, T. R., Pigg, R. M., & Grim, J. M. (2019). Knowing is half the battle: Assessments of both student perception and performance are necessary to successfully evaluate curricular transformation. PLoS ONE, 14(1). https://doi.org/10.1371/JOURNAL.PONE.0210030

Sihaloho, M., Bialangi, N., Mohamad, E., & Tangio, J. S. (2025). Optimalisasi Pembelajaran Kimia dengan Pendekatan Multi Representasi untuk Meningkatkan Pemahaman Konsep Hidrolisis Garam. Damhil: Jurnal Pengabdian Kepada Masyarakat, 4(1), 116–122. https://doi.org/10.37905/damhil.v4i1.32910

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

Suryadinata, A. M. I. (2025). Metode Ceramah Dalam Pendidikan Islam (Keuntungan dan Keterbatasannya) The Lecture Method in Islamic Education (its Advantages and Limitations). Jurnal Kolaboratif Sains, 8(6), 3458–3467. https://doi.org/10.56338/jks.v8i6.7674

Thompson, A. R., & Lake, L. P. O. (2023). Relationship between learning approach, Bloom's taxonomy, and student performance in an undergraduate Human Anatomy course. Advances in Health Sciences Education, 28(4), 1115–1130. https://doi.org/10.1007/S10459-023-10208-Z

Tornee, N., Bunterm, T., Lee, K., & Muchimapura, S. (2019). Examining the effectiveness of guided inquiry with problem-solving process and cognitive function training in a high school chemistry course. Pedagogies, 14(2), 126–149.

https://doi.org/10.1080/1554480X.2019.1597722

Umar, I., Tikollah, R. M., & Sato. (2022). Prestasi Belajar Akuntansi Keuangan Melalui Model Pembelajaran Problem Based Learning pada Siswa Kelas XI Akuntansi SMK Negeri 1 Wanggarasi Kab. Pohuwato Gorontalo Ismail. Jurnal Pemikiran Dan Pengembangan Pembelajaran, 4(1), 124–134.

Vroom Redden, A. M., Barton, C. M., & Willian, K. R. (2020). Combined Guided and Open Inquiry Project for an Upper Division Biochemistry Lab: Sugar Content, Enzymatic Properties of Lactase, and the Spoiling Process in Milk. Journal of Chemical Education, 97(5), 1430–1436. https://doi.org/10.1021/ACS.JCHEMED.9B00926

Wang, L., Hodges, G., & Lee, J. (2022). Connecting Macroscopic , Molecular , and Symbolic Representations with Immersive Technologies in High School Chemistry : The Case of Redox Reactions. Education Sciences, 12(428). https://doi.org/10.3390/ educsci12070428

Waruwu, M., Pu`at, S. N., Utami, P. R., Yanti, E., & Rusydiana, M. (2025). Metode Penelitian Kuantitatif: Konsep, Jenis, Tahapan dan Kelebihan. Jurnal Ilmiah Profesi Pendidikan, 10(1), 917–932. https://doi.org/10.29303/jipp.v10i1.3057

Winarni, S., Effendy, E., Budiasih, E., & Wonorahardjo, S. (2022). Constructing 'Concept Approval Strategy,' A Chemistry Learning Idea to Prevent Misconceptions Construcción. Quimica Education, 33(2), 159–180. http://dx.doi.org/10.22201/fq.18708404e.2022.2.79841

Wu, Q., Petsangsri, S., & Morris, J. (2022). Students' Technology, Cognitive, and Content Knowledge (TSCCK) Instructional Model Effect on Cognitive Load and Learning Achievement. Education Sciences, 12(12). https://doi.org/10.3390/EDUCSCI12120916

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 (JREC), 6(1), 68–82. https://doi.org/10.25299/jrec.2024.

Zahro, R. indah R. al, Subarkah, C. Z., Sukmawardani, Y., & Cahyanto, T. (2024). Ivestigasi Miskonsepsi Reaksi Kimia Multiple Refresentation Dalam Pembelajaran Kimia Peserta Didik Madrasah Aliyah Di Kota Bandung. UNESA Journal of Chemical Education, 13(2), 77–85.

Zahronada, A. A., Cahyono, E., & Sumarti, S. S. (2025). Chemistry in Education Small-Scale Chemistry Experiment in Guided Inquiry Learning to Improve Concept Understanding and Science Process Skills. Chemistry in Education, 14(2), 65–72. https://doi.org/10.15294/chemined.v14i2.30468

Zazkis, D., & Rouhani, A. (2024). A lens for exploring which dimensions contribute to a justification's proofiness. Journal of Mathematical Behavior, 76. https://doi.org/10.1016/J.JMATHB.2024.101204

.