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Effectiveness of the Constructivist Approach (Guided Inquiry) in Chemistry Learning: A Systematic Review

Pahriah[*], **Putu Budi Adnyana, I Putu Wisna Ariawan, I Gede Astra Wesnawa**
Postgraduate Education Sciences, Ganesha University of Education, Indonesia
[*]Corresponding Author e-mail: pahriah@studentundiksha.ac.id

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Abstract
This study aims to identify the effectiveness of the Guided Inquiry approach in enhancing critical thinking skills, learning motivation, conceptual understanding, and student learning outcomes in chemistry education. Utilizing the Systematic Literature Review (SLR) method, this research reviews various relevant studies from international and national databases such as Scopus, ERIC, and SINTA, employing focused keywords. The analyzed articles were selected based on inclusion criteria that encompassed topic relevance and the availability of empirical data, resulting in 27 final articles for further analysis. The qualitative analysis results indicate that Guided Inquiry not only improves students' conceptual understanding of chemistry concepts but also strengthens critical thinking skills and learning motivation. Quantitative findings demonstrate a pattern of increased effectiveness across various educational levels, with more significant results observed at the secondary education level compared to higher education. Several factors, such as the role of teacher facilitation and student readiness, were also identified as important influences on the success of this approach. This study recommends the integration of the Guided Inquiry approach into the chemistry education curriculum, accompanied by the development of technology-based modules and continuous training for educators, to maximize the potential for constructive learning.

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INTRODUCTION

Chemistry education is often perceived as challenging by students, primarily due to the multitude of abstract concepts such as chemical bonding, reactions, electrochemistry, and stoichiometry, which require deep understanding and critical thinking skills (Pratiwi et al., 2019). Many of these concepts cannot be grasped through rote memorization alone but necessitate reasoning that enables students to connect theories with real-world phenomena. However, the traditional teaching methods that remain dominant tend to focus on procedural memorization, often failing to encourage students to comprehend and relate chemistry material to the real world (Wardani et al., 2016). Consequently, there is an urgent need for teaching approaches that can more effectively instill conceptual understanding.

The constructivist approach, particularly Guided Inquiry, offers a potential solution to address these challenges. In this approach, students are actively engaged in constructing their own understanding through exploration and reflection, with teachers acting as facilitators (Kendall & Schussler, 2013). Through Guided Inquiry, students are encouraged to participate directly in the scientific investigation process, thereby not only gaining a deeper understanding of chemistry material but also developing critical thinking and metacognitive skills (Vilardo et al., 2016). Research indicates that this method can significantly enhance student learning outcomes, particularly in understanding abstract concepts such as particle structure and complex chemical reactions (Furtak et al., 2012).

Several studies support the effectiveness of Guided Inquiry in improving chemistry understanding and critical thinking skills. For instance, Furtak et al. (2012) found that this approach in science education is more effective than conventional methods in helping students grasp complex scientific concepts. Similar findings were reported by Pratiwi et al. (2019), where Guided Inquiry-based modules significantly improved students' conceptual understanding and critical thinking skills. This approach can also boost student motivation to learn, help reduce achievement gaps among students, and support deeper scientific process skills (Blanchard et al., 2010; Cheung, 2011).

Considering these benefits, this study aims to further investigate the effectiveness of the Guided Inquiry approach in chemistry education at the secondary and higher education levels through a systematic review. The focus is to evaluate the impact of this approach on students' critical thinking skills, learning motivation, conceptual understanding, and learning outcomes, as well as to identify patterns of success and challenges faced in its implementation. By paying attention to the differing needs and levels of student maturity across educational stages, this research is expected to provide evidence-based recommendations for educators to enhance the quality of chemistry education at various educational levels through the application of more effective constructivist approaches.

METHOD

This study employs a Systematic Literature Review (SLR) approach to evaluate the effectiveness of the Guided Inquiry approach in chemistry education. SLR was chosen because it allows for an in-depth analysis of relevant studies using systematic criteria. Article searches were conducted in both international and national databases, such as Scopus, ERIC, and SINTA, to ensure comprehensive coverage.

Literature Search Process

The literature search was conducted from September 5 to October 1, 2024, using specific keywords, including "Effectiveness of Constructivist Guided Inquiry Approach in Chemistry," "Impact of Guided Inquiry on Conceptual Understanding of Chemistry," and "Chemistry Learning Using Guided Inquiry." These keywords were selected to ensure that only studies relevant to the research objectives were identified.

Article Selection

The article selection process in this research involved applying strict inclusion and exclusion criteria to ensure the relevance and quality of the sources analyzed. The inclusion criteria included articles that discuss the effects of the Guided Inquiry approach in chemistry education, published within the time frame of 2018 to 2024, and published in journals indexed in SINTA, ERIC, or Scopus. Exclusion criteria were established to eliminate irrelevant articles, such as those lacking empirical data or review articles that do not thoroughly discuss the implementation of Guided Inquiry in chemistry education. By these criteria, it is expected that only studies meeting methodological standards and topic relevance will be analyzed further. From the initial search, 35 articles were identified. After screening titles and abstracts, 27 articles were selected for further analysis. Two independent experts were also involved in the selection process to validate the relevance of the chosen articles.

Data Analysis

Data were analyzed using content analysis techniques to identify key themes related to the effectiveness of the Guided Inquiry approach. Aspects analyzed included improvements in conceptual understanding, critical thinking skills, learning motivation, and student learning outcomes. This data was then synthesized to identify best practices, challenges, and patterns in the application of the Guided Inquiry method in chemistry classes. Simple quantitative analysis was also performed to observe the distribution of Guided Inquiry applications across different educational levels and to uncover patterns of success and barriers in implementation.

Presentation of Results

The results of the analysis are presented in the form of tables and graphs to provide clear visualization and support data interpretation. The synthesis of the analysis results also includes comparisons with other studies employing different approaches, thus providing a comprehensive overview of the effectiveness of the Guided Inquiry approach in chemistry education.

RESULTS AND DISCUSSION

The table below presents a summary of findings from studies examining the effectiveness of inquiry-based approaches in chemistry education.

Table 1. List of selected paper

No	Authors	Findings	Educational Level
1	Aidoo, B. et al. (2022)	The flipped inquiry-based learning (FIBL) approach enhances students' academic performance and critical thinking skills.	Higher Education
2	Ribić, L. et al. (2024)	Inquiry-based chemistry education in non-formal settings increases interest and motivation among gifted students.	Junior High School
3	Prasetya (2023)	The guided inquiry model significantly improves students' conceptual understanding and critical thinking skills.	Higher Education
4	Prapti Utami, R. & Rohaeti, E. (2019)	Inquiry-based learning with Macromedia Flash enhances students' conceptual understanding.	Senior High School
5	Twizeyimana, E. et al. (2024)	Inquiry-based learning improves students' academic performance and enthusiasm for science.	Senior High School
6	Li, X. et al. (2024)	Science teachers' beliefs significantly influence students' science process skills.	Senior High School
7	Papalazarou, N. et al. (2024)	There is no significant difference between physical and virtual inquiry in students' conceptual understanding.	Senior High School
8	Al Mamun, M. A. & Lawrie, G. (2023)	Students' interaction with content increases behavioral engagement in online learning.	Higher Education
9	Erenler, S. et al. (2024)	Argument-Driven Inquiry (ADI) activities enhance pre-service teachers' understanding of the Nature of Scientific Inquiry (NOSI).	Higher Education
10	Denton, N. L. & Kulesza, A. E. (2024)	Team-based inquiry laboratory course design increases students' persistence in science.	Higher Education

No	Authors	Findings	Educational Level
11	Afifah, U. N. & Azizah, U. (2021)	The guided inquiry model based on blended learning improves students' metacognitive skills.	Senior High School
12	Juniar, A. & Sianipar, I. A. (2022)	The guided inquiry model enhances students' science process skills and learning outcomes in chemical equilibrium material.	Senior High School
13	Ramdoniati, N. (2020)	The guided inquiry model with a contextual approach improves students' science process skills and learning outcomes.	Senior High School
14	Laliyo, L. A. et al. (2020)	The guided inquiry learning model enhances students' problem-solving abilities related to basic chemical laws.	Senior High School
15	Paramita, A. K. et al. (2021)	Guided inquiry learning with a STEM approach improves students' conceptual understanding and argumentation skills.	Senior High School
16	Ibad, E. (2018)	Inquiry-based chemistry laboratories enhance students' critical thinking skills.	Higher Education
17	Pratiwi, I., Ismanisa, I., & Nugraha, A. (2019)	Inquiry-based chemistry laboratories improve students' critical thinking skills.	Higher Education
18	Utami, S. & Sundari, S. (2019)	Inquiry-based learning enhances students' achievements in chemistry subjects.	Senior High School
19	Muhali, M., Asy'ari, M., & Sukaisih, R. (2021)	The guided inquiry model integrated with virtual laboratories improves conceptual understanding and metacognitive skills.	Senior High School
20	Sofha, A. (2022)	Guided inquiry-based practical worksheets develop students' science process skills.	Senior High School
21	Saija, M. & Beay, L. (2022)	Guided inquiry-based learning materials enhance students' conceptual understanding and motivation to learn.	Higher Education
22	Ferreira, D. et al. (2021)	Inquiry-based approaches increase students' intrinsic motivation to learn chemistry.	Senior High School
23	Gupta, T. et al. (2014)	The guided inquiry approach improves students' critical thinking abilities.	Higher Education
24	Asni, A., Wildan, W., & Hadisaputra, S. (2020)	The guided inquiry model enhances chemistry learning outcomes in hydrocarbon material.	Senior High School
25	Ischak, N. I. et al. (2020)	The guided inquiry model improves students' learning outcomes in acid-base solution material.	Senior High School
26	Umar, S. & Limatahu, N. A. (2021)	The guided inquiry model enhances learning outcomes of X-grade students in basic chemical law material.	Senior High School
27	Hariani, N. R. et al. (2020)	The guided inquiry model supported by e-modules improves understanding of salt hydrolysis concepts.	Senior High School

Effectiveness of Inquiry-Based Learning Model on Conceptual Understanding, Critical Thinking Skills, Motivation, and Student Learning Outcomes in Chemistry Learning

The Effect of Inquiry-Based Learning Model on Conceptual Understanding

The inquiry-based learning model has been shown to be effective in enhancing students' conceptual understanding by promoting active engagement. In this learning process, students are given the opportunity to observe, experiment, and reflect, allowing them to comprehend the material in greater depth. This approach helps students become independent and critical learners.

Several studies support the effectiveness of this model. Utami and Rohaeti (2019) found that the use of multimedia in inquiry-based learning can improve students' conceptual understanding in chemistry lessons. Additionally, research by Papalazarou et al. (2024) demonstrates that both physical and virtual laboratories are effective in enhancing conceptual understanding, underscoring the flexibility in applying inquiry-based learning. Hariani et al. (2020) revealed that the use of e-modules in guided inquiry models significantly improves student understanding, particularly on complex topics. Prasetya (2023) also added that the implementation of this model in higher education shows significant increases in students' conceptual understanding.

A comparison between physical and virtual laboratories shows comparable results regarding students' conceptual understanding. This provides options for educational institutions to choose the method that best suits their available resources. Virtual laboratories, in particular, offer opportunities for students to explore concepts that may be difficult to access in a physical environment. Overall, inquiry-based learning demonstrates a positive impact on students' conceptual understanding, both at the school and higher education levels. This approach enables students to learn actively, adapt to technology, and build more solid knowledge through hands-on experiences.

Enhancement of Critical Thinking Skills and Scientific Process Skills

The inquiry-based learning model has proven effective in enhancing students' critical thinking skills. Aidoo et al. (2022) explain that by challenging students to formulate hypotheses, plan experiments, and analyze results, they are encouraged to think critically. This process involves evaluating information and making decisions, which significantly enhances students' analytical abilities. Thus, the inquiry learning model not only helps students understand the material but also develops a more complex and critical way of thinking. In addition to improving critical thinking skills, the application of laboratories, both physical and virtual, within the inquiry-based learning model significantly contributes to the development of scientific process skills. Research by Juniar and Sianipar (2022) shows that students engaged in inquiry-based experiments experience improvements in observation, measurement, and data analysis skills. Direct involvement in this scientific process not only strengthens conceptual understanding but also provides valuable practical experiences for students.

Other research findings also support the effectiveness of this model. Sofha (2022) highlights that the inquiry learning model allows students to participate more actively in learning activities, thereby encouraging the simultaneous development of critical thinking and scientific process skills. Gupta et al. (2014) add that students engaged in inquiry-based learning are able to formulate research questions, design experiments, and reflect on their experimental results, which are essential elements of scientific process skills. Overall, the implementation of the inquiry-based learning model creates a learning environment that supports the development of critical thinking and scientific process skills. By encouraging students to actively engage in the learning process, they not only comprehend the concepts taught but also build essential abilities needed in the scientific world and everyday life. This indicates that the inquiry-based learning model is not merely a teaching method but also a comprehensive educational strategy in preparing students for future challenges.

Motivation and Engagement in Chemistry Learning

The inquiry-based learning model has been proven to enhance students' learning motivation, particularly among gifted students. Ribić et al. (2024) demonstrate that by providing students the opportunity to explore chemical concepts through questions and experiments, they feel more engaged and motivated. This approach not only makes learning more interesting but also helps students recognize the relevance of chemical concepts in everyday life. Thus, inquiry-based learning serves as an effective tool to stimulate curiosity and interest in chemistry. Student engagement in the learning process also significantly increases when using the inquiry-based learning model. Ferreira et al. (2021) studied the impact of this approach and found that students learning through inquiry are more actively participating in discussions, group work, and practical activities. This engagement creates a dynamic and collaborative learning environment, which in turn fosters deeper and more meaningful learning. Such an active environment is crucial to ensure that students are not just recipients of information but also contributors to the learning process.

Research by Al Mamun and Lawrie (2023) also shows that gifted students engaged in inquiry-based learning experience significant increases in their motivation and involvement. They feel more empowered to explore new ideas and develop their research skills. This is especially important in the development of gifted students' potential, who often seek greater challenges in their learning. Thus, the inquiry-based learning model not only provides support for students in general but also facilitates the specific needs of gifted students. Overall, the implementation of the inquiry-based learning model in chemistry classes not only enhances students' learning motivation but also strengthens their engagement in the learning process. By creating an atmosphere that supports exploration and discovery, students can be more actively involved in learning, contributing to better mastery of chemical concepts. This is particularly relevant in the context of education that increasingly prioritizes a student-centered approach, where students are encouraged to be active agents in their own learning process.

Improvement in Student Learning Outcomes

The guided inquiry learning model has proven effective in improving student learning outcomes in chemistry education. According to Utami & Sundari (2019), the application of this approach helps students understand fundamental chemistry concepts better. By providing guidance in the investigation process, students can develop a deeper and more structured understanding of the material being studied. This indicates that appropriate guidance can facilitate the learning process and help students be better prepared to face academic challenges. Additionally, Saija & Beay (2022) reveal that students engaged in guided inquiry learning show significant improvements in their mastery of fundamental chemistry concepts. In their study, students learning through this method not only recall information but are also able to apply those concepts in new situations. This shows that the inquiry approach focuses not only on information mastery but also encourages students to think critically and analytically when facing more complex problems.

Research by Umar & Limatahu (2021) examined the effectiveness of guided inquiry in other chemistry topics and found that this model also successfully improved student learning outcomes on more complex topics. Their research results indicate that students involved in active experiments and discussions tend to achieve higher scores on exams and practical assessments. This indicates that active involvement in the learning process can enhance students' understanding and academic achievement, making them more prepared to face exams and challenges in chemistry learning. Overall, the improvement in student learning outcomes through the guided inquiry approach provides important implications for chemistry teaching. Teachers can leverage this approach to create more interactive and participatory learning experiences. By providing opportunities for students to investigate and discover information independently, the learning process becomes more engaging and effective. This approach not only supports better academic achievements but also develops critical and creative thinking skills that are essential for students in a constantly changing world.

Differences in the Effectiveness of Inquiry Models at Various Educational Levels

Secondary Education (Junior High School and Senior High School)

The implementation of inquiry learning models shows significant differences in effectiveness across various educational levels, particularly at the secondary level, such as junior high school (SMP) and senior high school (SMA). Ribić et al. (2024) note that at the junior high school level, inquiry learning models yield significant results in enhancing students' learning skills. Students engaged in guided inquiry activities experience improvements in their understanding of fundamental concepts, critical thinking skills, and learning motivation. The structured inquiry process allows them to explore chemical concepts more deeply, leading to better mastery of the material.

At the senior high school level, research by Twizeyimana et al. (2024) indicates that inquiry learning models have a more profound positive impact. Senior high school students tend to be better able to connect chemical concepts with real-world applications, thanks to a more complex learning approach. The inquiry model enables them to design experiments, analyze data, and draw conclusions, significantly enhancing their learning outcomes and science process skills. Consequently, senior high school students can develop a broader and more applicable understanding of the material being taught.

Paramita et al. (2021) also emphasize the importance of implementing inquiry models in non-formal environments for both junior and senior high school students. In this context, guided inquiry can be conducted through extracurricular activities, workshops, or community service programs that involve students in practical research. This involvement not only strengthens students' academic understanding but also enhances their motivation and interest in learning chemistry. Non-formal environments provide opportunities for students to collaborate, experiment, and learn in more flexible and supportive contexts.

In comparing the results between the two educational levels, research shows that senior high school students often demonstrate a more significant improvement in learning outcomes than junior high school students, even though both benefit from inquiry models. This may be due to differences in the level of understanding and maturity of students at each educational level. Senior high school students tend to have a stronger knowledge background and the ability to think more abstractly, which supports their understanding of more complex concepts. Thus, the implementation of inquiry learning models needs to be tailored to the characteristics and needs of students at each educational level to achieve optimal results.

Higher Education (University)

The application of inquiry learning models in higher education demonstrates significant effectiveness in enhancing students' conceptual understanding, science process skills, perseverance, and motivation. Prasetya (2023) states that inquiry-based learning models encourage students to actively explore and delve into information, reinforcing their understanding of complex concepts in chemistry. In this way, inquiry learning not only facilitates knowledge transfer but also enhances students' ability to apply those concepts in new situations, which is essential for advanced chemistry studies.

Denton & Kulesza (2024) emphasize that inquiry learning models, especially those based in laboratories, are highly effective in improving students' science process skills. Students' involvement in self-designed experiments allows them to learn how to formulate hypotheses, design experiments, and analyze results critically and systematically. This experience not only builds their confidence in laboratory skills but also prepares them to face greater challenges in scientific research and future careers.

Furthermore, Erenler et al. (2024) demonstrate that inquiry-based learning contributes to the enhancement of students' perseverance. By providing students with the freedom to explore and solve problems independently, they feel more engaged and responsible for their learning process. This model encourages students to focus not only on the final results but also on the learning journey itself, which in turn enhances their motivation and perseverance in facing academic challenges.

In the context of laboratory-based learning, inquiry models provide students with opportunities to apply the theories they learn in real practice. Laboratory learning involving inquiry allows students to experience the scientific process firsthand, which is very different from more traditional theoretical learning. Through experiments, they learn to adapt to errors, formulate research questions, and collaborate in groups, facilitating a richer and more profound learning experience. Thus, the application of inquiry learning models in higher education holds great potential in preparing students to face academic and professional challenges in the future.

Models of Inquiry-Based Learning Used in Chemistry Education

Guided Inquiry

Guided inquiry is a learning model where teachers provide clear guidance to students during exploration and research processes, aimed at helping students understand complex chemistry concepts in a structured manner. Utami & Sundari (2019) explain that guided inquiry provides a framework that allows students to actively participate in learning while still receiving support from teachers. The implementation of this model in chemistry education involves a series of steps that facilitate students in asking questions, formulating hypotheses, and conducting experiments. Ramdoniati (2020) emphasizes that in this process, teachers act as facilitators who help students navigate the research steps, ensuring they do not feel lost. Additionally, group discussions are also a crucial part of this model, allowing students to share findings and reflect on the processes they have undergone.

Asni et al. (2020) state that guided inquiry significantly improves students' conceptual understanding in chemistry. By conducting research under teacher guidance, students can more easily grasp the relationship between theory and practice. The experiments carried out during guided inquiry not only enhance student engagement but also provide hands-on experiences that help them internalize chemistry concepts. Furthermore, guided inquiry is also effective in improving students' scientific process skills. In this learning process, students are trained to think critically and analytically as they design experiments and analyze data. Utami & Sundari (2019) emphasize that skills such as observation, measurement, and data interpretation are heavily emphasized in this model, helping students develop the necessary skills for scientific research.

The success of implementing the guided inquiry model heavily relies on the active role of teachers in supporting and guiding students. Ramdoniati (2020) highlights the importance of training for teachers to understand how to apply this model effectively, so they can provide constructive feedback during the learning process. Thus, students feel more confident in exploring and delving into the world of chemistry, ultimately supporting their academic achievements.

Technology-Integrated Inquiry-Based Learning

Technology-integrated inquiry-based learning refers to the use of technological tools and resources, such as virtual laboratories and digital modules, to support the inquiry learning process. This approach allows students to explore chemistry concepts interactively and innovatively, expanding the limits of conventional learning often hindered by physical resource constraints. Muhali et al. (2021) explain that virtual laboratories offer safe and flexible practical experiences, where students can conduct chemistry experiments in a simulated environment. This is particularly beneficial for schools lacking adequate laboratory facilities, as through virtual laboratories, students can test hypotheses, collect data, and analyze results in the same way as in real laboratories, but without the high risks and costs.

Hariani et al. (2020) emphasize the importance of digital modules in inquiry-based learning. These modules are designed to provide the necessary information and guidance during the research process, allowing students to access teaching materials independently and explore chemistry topics in depth. The use of digital modules is often accompanied by interactive elements, such as quizzes and videos, which can enhance student engagement. Moreover, integrating technology into inquiry-based learning has proven effective in improving students' metacognitive skills, including the ability to plan, monitor, and evaluate their learning processes. Through the use of virtual laboratories and digital modules, students learn to reflect on their learning experiences, understand what they have learned, and identify areas that need improvement. Muhali et al. (2021) show that students engaged in technology-supported inquiry-based learning demonstrate significant improvements in their metacognitive skills.

Technology-integrated inquiry-based learning not only enhances metacognitive skills but also contributes to a better understanding of chemistry concepts. Hariani et al. (2020) note that students participating in inquiry-based learning with technological support show significant improvements in their understanding of fundamental chemistry concepts. Interacting with simulations and digital modules allows students to see chemistry concepts in more real-world contexts, making it easier for them to understand the practical applications of the theories studied. However, there are challenges that need to be addressed, such as technology accessibility and training for teachers. Investment in technological infrastructure and professional development for educators is necessary to ensure the effectiveness of this learning approach. Recommendations from Muhali et al. (2021) and Hariani et al. (2020) include enhancing technical support in schools and developing curricula that effectively integrate technology into chemistry learning.

Blended Learning and Argument-Driven Inquiry (ADI)

Blended learning and Argument-Driven Inquiry (ADI) are two learning models with great potential in chemistry education. Blended learning is an approach that combines face-to-face learning with online learning, while ADI emphasizes the development of scientific arguments based on evidence. When applied in the context of chemistry education, both models can enhance student engagement and mastery of scientific concepts. Afifah & Azizah (2021) explain that blended learning provides students with a more flexible learning experience, allowing them to learn at their own pace. By combining face-to-face sessions and online materials, students can deepen their understanding through interaction with the material outside the classroom.

On the other hand, Erenler et al. (2024) explain that ADI focuses on developing students' critical thinking and argumentation skills. In this model, students are invited to formulate questions, conduct experiments, and construct arguments based on the data obtained. This process not only helps students understand chemistry concepts but also equips them with important skills in evidence-based decision-making. The combination of blended learning and ADI has the potential to enhance students' metacognitive skills, where students are engaged in active learning and are encouraged to reflect on their thinking processes. In the context of ADI, students must evaluate their arguments and consider alternative perspectives, contributing to the development of metacognitive awareness (Afifah & Azizah, 2021).

The application of these two models shows significant improvements in students' understanding of scientific concepts. Erenler et al. (2024) note that students involved in blended learning and ADI can more effectively connect theory with practice, thereby strengthening their mastery of the material. Despite the many benefits, blended learning and ADI also face challenges, such as the need for training for educators for effective implementation and students' access to the necessary technology. Recommendations from Afifah & Azizah (2021) and Erenler et al. (2024) include enhancing technical support and developing curricula that reflect the integration of both models, as well as creating learning environments that support collaboration and communication among students.

Challenges and Implications of Inquiry-Based Learning in Chemistry Education

Challenges in Implementing Inquiry-Based Learning

Inquiry-based learning in chemistry education faces several challenges during its implementation. One of the primary challenges is the limited time available within the curriculum, as inquiry-based teaching often requires more time for exploration, discussion, and reflection compared to traditional teaching methods. Many teachers feel pressured to complete the curriculum within the allocated timeframe, leading them to overlook more in-depth inquiry approaches. Additionally, the availability of resources is a significant factor in the execution of this learning method. The implementation of inquiry-based learning heavily relies on the availability of physical facilities, such as laboratories and teaching aids, as well as educational resources like textbooks, software, and access to technology. In many schools, particularly in areas with limited budgets, these resources are often inadequate, hindering the effectiveness of inquiry methods.

Another significant challenge is the preparedness of teachers to implement this method. Many teachers may not have received specific training in inquiry teaching techniques and feel less confident in managing a classroom with this approach. They often struggle to design inquiry activities that align with the applicable curriculum standards, ultimately leading to resistance to changes in teaching methods. Therefore, it is crucial to provide appropriate support and training to teachers so they can overcome these challenges and effectively implement inquiry-based learning in chemistry education.

Implications for Curriculum Development and Teacher Training

The implications for curriculum development and teacher training in the application of inquiry-based learning are critical to ensuring the effectiveness of this method. Support from educational institutions is a key factor, which includes providing adequate resources, developing curricula that support inquiry implementation, and creating conducive learning environments. Institutions need to commit to integrating inquiry-based learning into educational standards and facilitating teachers' access to the necessary materials and tools. Furthermore, continuous teacher training should be a top priority. Regular training sessions and workshops can help teachers understand and apply inquiry teaching strategies with greater confidence, as well as develop skills in managing a more active classroom dynamic and designing learning experiences that foster student exploration and discovery.

Collaboration among educators at the school level and across educational institutions is also crucial in this context. By sharing best practices, resources, and experiences, teachers can support one another in addressing the challenges encountered in implementing inquiry-based learning. Establishing learning communities can strengthen the understanding and broader implementation of these methods. Additionally, the implementation of inquiry-based learning should be accompanied by effective evaluation mechanisms. Feedback from students and teachers regarding the learning experience can provide valuable insights for future improvements. Continuous evaluation will also help tailor teaching methods to meet the needs and contexts of students, making learning more relevant and effective.

CONCLUSION

This study successfully identified the effectiveness of the Guided Inquiry approach in enhancing critical thinking skills, learning motivation, conceptual understanding, and learning outcomes among students in chemistry education across various educational levels. The analysis results indicate that the application of this approach not only aids students in better understanding chemical concepts but also enhances their motivation to learn. There is a significant difference in effectiveness between the application of inquiry models at secondary and higher education levels, suggesting that the needs and characteristics of students at each level must be considered in curriculum development. Therefore, the Guided Inquiry approach has proven to be an effective alternative in addressing the challenges of chemistry learning that are often perceived as difficult by students.

RECOMMENDATIONS

Based on the findings of this study, it is recommended that:

1. **Curriculum Integration:** The Guided Inquiry-based learning model should be more broadly integrated into the chemistry education curriculum at both the secondary and higher education levels to enhance student engagement and learning outcomes.
2. **Module Development:** Learning modules that support the inquiry approach should be developed utilizing technology, allowing students to become more actively involved in the learning process.
3. **Teacher Training:** Continuous training for educators is essential to ensure they understand and can effectively implement the Guided Inquiry approach in the classroom.
4. **Further Research:** Additional research is needed to explore the factors influencing the effectiveness of this approach's implementation in various contexts and to address the challenges encountered during its execution.

BIBLIOGRAPHY

Afifah, U. N., & Azizah, U. (2021). Implementation of guided inquiry based on blended learning to improve students' metacognitive skills in reaction rate. *IJCER (International Journal of Chemistry Education Research)*, 1-11. https://doi.org/10.20885/ijcer.vol5.iss1.art1

Aidoo, B., Anthony-Krueger, C., Gyampoh, A., Tsyawo, N., & Quansah, F. (2022). A mixed-method approach to investigate the effect of flipped inquiry-based learning on chemistry students learning. *European Journal of Science and Mathematics Education, 10*(4), 507-518. https://doi.org/10.30935/scimath/12339

Al Mamun, M. A., & Lawrie, G. (2023). Student-content interactions: Exploring behavioural engagement with self-regulated inquiry-based online learning modules. *Smart learning environments*, *10*(1), 1. https://doi.org/10.1186/s40561-022-00221-x

Alghamdi, A. K., & Alanazi, F. H. (2020). Process-Oriented Guided-Inquiry Learning in Saudi Secondary School Chemistry Instruction. *Eurasia Journal of Mathematics, Science and Technology Education*, *16*(12). https://doi.org/10.29333/ejmste/9278

Asni, A., Wildan, W., & Hadisaputra, S. (2020). Pengaruh model pembelajaran inkuiri terbimbing terhadap hasil belajar kimia siswa materi pokok hidrokarbon. *Chemistry Education Practice*, *3*(1), 17-22. https://doi.org/10.29303/cep.v3i1.1450

Blanchard, M. R., Southerland, S. A., Osborne, J. W., Sampson, V. D., Annetta, L. A., & Granger, E. M. (2010). Is inquiry possible in light of accountability?: A quantitative comparison of the relative effectiveness of guided inquiry and verification laboratory instruction. *Science education*, *94*(4), 577-616. https://doi.org/10.1002/sce.20390

Cheung, D. (2011). Teacher beliefs about implementing guided-inquiry laboratory experiments for secondary school chemistry. *Journal of Chemical Education*, 88(11), 1462-1468. https://doi.org/10.1021/ed1008409

Cresswell, S. and Loughlin, W. (2017). A case-based scenario with interdisciplinary guided-inquiry in chemistry and biology: experiences of first year forensic science students. *Journal of Chemical Education*, 94(8), 1074-1082. https://doi.org/10.1021/acs.jchemed.6b00827

Denton, N. L., & Kulesza, A. E. (2024). Inquiry-Team-Based Lab Course Design Enhances Underrepresented Undergraduate Predictors of Persistence in the Sciences. *Medical Science Educator*, 1-10. https://doi.org/10.1007/s40670-024-02014-y

Erenler, S., Cetin, P. S., & Eymur, G. (2024). Impact of Argument-Driven Inquiry Activities on Pre-service Science Teachers' Views of the Nature of Scientific Inquiry in the Context of Climate Change Education. *Science & Education*, 1-31. https://doi.org/10.1007/s11191-024-00512-4

Ferreira, D., Sentanin, F., Parra, K., Bonini, V., Castro, M., & Kasseboehmer, A. (2021). Implementation of inquiry-based science in the classroom and its repercussion on the motivation to learn chemistry. *Journal of Chemical Education*, *99*(2), 578-591. https://doi.org/10.1021/acs.jchemed.1c00287

Furtak, E. M., Seidel, T., Iverson, H., & Briggs, D. C. (2012). Experimental and quasi-experimental studies of inquiry-based science teaching: A meta-analysis. *Review of educational research*, *82*(3), 300-329. https://doi.org/10.3102/0034654312457206

Gupta, T., Burke, K., Mehta, A., & Greenbowe, T. (2014). Impact of guided-inquiry-based instruction with a writing and reflection emphasis on chemistry students' critical thinking abilities. *Journal of Chemical Education, 92*(1), 32-38. https://doi.org/10.1021/ed500059r

Hariani, N. R., Nuswowati, M., & Winarno, W. (2020). Pengaruh penerapan model inkuiri terbimbing berbantuan e-modul terhadap pemahaman konsep hidrolisis garam. *Jurnal Inovasi Pendidikan Kimia*, *14*(1), 2561-2571.

Ibad, E. (2018). The effect of inquiry based chemistry laboratory on critical thinking. *Journal of International Scientific Researches*. https://doi.org/10.21733/ibad.423570

Ischak, N. I., Odja, E. A., La Kilo, J., & La Kilo, A. (2020). Pengaruh Keterampilan Proses Sains Melalui Model Inkuiri Terbimbing terhadap Hasil Belajar Siswa pada Materi Larutan Asam Basa. *Hydrogen: Jurnal Kependidikan Kimia*, *8*(2), 58-66. https://doi.org/10.33394/hjkk.v8i2.2748

Juniar, A., & Sianipar, I. A. (2022). The influence of guided inquiry learning models on science process skills and student learning outcomes on chemical equilibrium material. *Jurnal Pendidikan Kimia*, *14*(2), 79-84. https://doi.10.24114/jpkim.v14i2.34553

Kendall, K. D., & Schussler, E. E. (2013). Evolving impressions: Undergraduate perceptions of graduate teaching assistants and faculty members over a semester. *CBE—Life Sciences Education*, *12*(1), 92-105. https://doi.org/10.1187/cbe.12-07-0110

Laliyo, L. A., Kau, M., La Kilo, J., La Kilo, A., & No, J. J. S. (2020). Kemampuan siswa memecahkan masalah hukum-hukum dasar kimia melalui pembelajaran inkuiri terbimbing. *Ar-Razi Jurnal Ilmiah*, *8*(1), 1-8. http://dx.doi.org/10.29406/ar-r.v8i1.1875

Laredo, T. (2013). Changing the first-year chemistry laboratory manual to implement a problem-based approach that improves student engagement. *Journal of Chemical Education*, 90(9), 1151-1154. https://doi.org/10.1021/ed300313m

Li, X., Zhang, Y., Yu, F., Zhang, X., Zhao, X., & Pi, Z. (2024). Do science teachers' believes related to inquiry-based teaching affect students' science process skills? Evidence from a multilevel model analysis. *Disciplinary and Interdisciplinary Science Education Research*, *6*(1), 1. https://doi.org/10.1186/s43031-023-00089-y

Mistry, N. and Shahid, N. (2021). Design and delivery of virtual inquiry-based organic chemistry experiments. Journal of Chemical Education, 98(9), 2952-2958. https://doi.org/10.1021/acs.jchemed.1c00571

Muhali, M., Asy'ari, M., & Sukaisih, R. (2021). Model pembelajaran inquiry terbimbing terintegrasi laboratorium virtual untuk meningkatkan pemahaman konsep dan keterampilan metakognitif siswa. *Empiricism Journal*, *2*(2), 73-84. https://doi.org/10.36312/ej.v2i2.594

Muhali, M., Talib, M. A., & Merdiana, D. (2021). Guided inquiry model with virtual laboratory to enhance students' conceptual understanding and metacognitive skills. *Jurnal Pendidikan Kimia*, *13*(1), 38-44. https://doi.org/10.29407/jpk.v13i1.18571

Nicol, C. B., Gakuba, E., & Habinshuti, G. (2022). Effects of Inquiry-Based Chemistry Experimentation on Students' Attitudes towards the Teaching and Learning of Chemistry. *Journal of Baltic Science Education*, *21*(4), 663-679. https://doi.org/10.33225/jbse/22.21.663

Papalazarou, N., Lefkos, I., & Fachantidis, N. (2024). The Effect of Physical and Virtual Inquiry-Based Experiments on Students' Attitudes and Learning. *Journal of Science Education and Technology*, *33*(3), 349-364. https://doi.org/10.1007/s10956-023-10088-3

Paramita, A. K., Yahmin, Y., & Dasna, I. W. (2021). *Pembelajaran inkuiri terbimbing dengan pendekatan stem (science, technology, engineering, mathematics) untuk pemahaman konsep dan keterampilan argumentasi siswa SMA pada materi laju reaksi* (Doctoral dissertation, State University of Malang). https://doi.10.17977/jptpp.v5i11.14189

Prapti Utami, R., & Rohaeti, E. (2019). Students' Concept Understanding in Chemistry Learning Using Macromedia Flash Based Inquiry Learning. *Online Submission*, *10*(3), 1-12.

Prasetya, C. (2023). The implementation of the guided inquiry model in basic chemistry courses. Journal of Educational Chemistry (Jec), 5(1), 27-34. https://doi.org/10.21580/jec.2023.5.1.16132

Pratiwi, I., Ismanisa, I., & Nugraha, A. (2019). Development of guided inquiry based modules to improve learning outcomes and metacognition skills of student. *Jurnal Pendidikan Kimia*, *11*(2), 49-56. https://doi.org/10.24114/jpkim.v11i2.14462

Pratiwi, I., Sari, R. R., & Utami, I. (2019). The effectiveness of guided inquiry-based module on improving students' learning outcomes and metacognition skills. *Jurnal Pendidikan Kimia*, *11*(1), 35-42. https://doi.org/10.29407/jpk.v11i1.19474

Ramdoniati, N. (2020). Pengaruh Model Inkuiri Terbimbing Dengan Pendekatan Kontekstual Terhadap Keterampilan Proses Sains Dan Hasil Belajar Siswa. *NUSANTARA*, *2*(3), 520-529.

RibiÄ, L., Devetak, I., & Vinko, L. (2024). Inquiry-Based Chemistry Education Activities in a Non-formal Educational Setting for Gifted Students. *Center for Educational Policy Studies Journal*, *14*(1), 143-169. https://doi.org/10.26529/cepsj.1706

Saija, M., & Beay, L. (2022). LKM berbasis inkuiri terbimbing untuk meningkatkan pemahaman konseptual dan motivasi belajar kimia. *Jambura Journal of Educational Chemistry*, *4*(1), 1-7. https://doi.org/10.34312/jjec.v4i1.13492

Saija, M., & Beay, L. (2022). The effectiveness of guided inquiry-based student worksheets in improving students' conceptual understanding and motivation. *International Journal of Science and Mathematics Education*, *20*(5), 839-856. https://doi.org/10.1007/s10763-021-10265-5

Şen, Ş., Yılmaz, A., & Geban, Ö. (2015). The effects of process oriented guided inquiry learning environment on students' self-regulated learning skills. Problems of Education in the 21st Century, 66(1), 54-66. https://doi.org/10.33225/pec/15.66.54

Sofha, A. (2022). Practical student worksheets based on guided inquiry to develop students' science process skills. *Journal of Education and Learning*, *16*(2), 186-195. https://doi.org/10.5539/jel.v16n2p186

Twizeyimana, E., Shyiramunda, T., Dufitumukiza, B., & Niyitegeka, G. (2024). Teaching and learning science as inquiry: an outlook of teachers in science education. *SN Social Sciences*, *4*(2), 40. https://doi.org/10.1007/s43545-024-00846-4

Umar, S., & Limatahu, N. A. (2021). Pengaruh Model Pembelajaran Inkuiri Terbimbing Terhadap Hasil Belajar Siswa Kelas X Sma Negeri 37 Halmahera Selatan Pada Materi Hukum Dasar Kimia. *Jurnal Pendidikan Kimia Unkhair (JPKU)*, *1*(2). https://doi.org/10.33387/jpku.v1i2.5095

Utami, S., & Sundari, S. (2019). The impact of inquiry-based learning on students' achievement in chemistry. *Jurnal Pendidikan Kimia*, *11*(2), 126-132. https://doi.org/10.29407/jpk.v11i2.22488

Vilardo, D., MacKenzie, A., & Yezierski, E. (2016). Using students' conceptions of air to evaluate a guided-inquiry activity classifying matter using particulate models. Journal of Chemical Education, 94(2), 206-210. https://doi.org/10.1021/acs.jchemed.5b01011

Wardani, S., Nurhayati, S., & Safitri, A. (2016). The Effectiveness of the Guided Inquiry Learning Module towards Students' Character and Concept Understanding. *International Journal of Science and Research (IJSR)*, *5*(6), 1589-1594. https://doi.org/10.21275/v5i6.nov164512