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# Guided Inquiry-Based Learning in Biotechnology: Effects on Students' Scientific Attitudes and Academic Achievement at Menglait Middle School Brunei Darsussalam

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**ABSTRACT**

This study investigates the effects of guided inquiry-based learning on students' scientific attitudes and academic achievement in biotechnology at Menglait Middle School, Brunei Darussalam. Employing a quasi-experimental design, two groups of Year 9 students were involved: the experimental group received biotechnology instruction through guided inquiry-based learning, while the control group experienced conventional teaching methods. Data were collected using a scientific attitude questionnaire and a standardized academic achievement test in biotechnology. The findings revealed a statistically significant improvement in both scientific attitudes and academic achievement among students in the experimental group compared to the control group. Guided inquiry not only fostered curiosity and a more positive attitude toward science but also enhanced students' conceptual understanding and problem-solving skills. These results underscore the importance of implementing inquiry-based approaches in science education to promote deeper learning and attitudinal development. The study recommends integrating guided inquiry strategies into the science curriculum to support 21st-century learning goals. Moreover, teacher training programs should emphasize the facilitation of inquiry to ensure effective implementation. This research contributes to the growing body of evidence highlighting the pedagogical value of inquiry-based learning in secondary education, particularly in the context of biotechnology, a subject critical for scientific literacy in modern society.

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## INTRODUCTION

Science education in the 21st century demands instructional approaches that not only enhance students' academic performance but also foster positive scientific attitudes. One instructional model that has gained considerable attention is guided inquiry-based learning, which positions students at the center of the learning process through exploration, discovery, and reflection. This approach has been shown to improve conceptual understanding, critical thinking, and scientific attitudes (Guerrero & Bautista, 2023).

Biotechnology, as a rapidly evolving and multidisciplinary scientific field, offers an exceptionally rich and dynamic context for the application of inquiry-based learning models such as Guided Inquiry-Based Learning (GIBL). The nature of biotechnology—encompassing areas such as genetic engineering, microbiology, and bioethics—demands not only a solid understanding of theoretical principles but also the development of essential scientific process skills, including observation, data analysis, problem-solving, and critical thinking. Additionally, because biotechnology often intersects with real-world issues such as health, agriculture, and environmental sustainability, it naturally fosters the cultivation of reflective and ethical attitudes in students, encouraging them to consider the broader social implications of scientific advancement. Given these attributes, biotechnology serves as an ideal subject area to promote student-centered, inquiry-driven approaches that mirror authentic scientific practices.

However, despite the clear potential and relevance of inquiry-based instruction in biotechnology education, the current reality in many schools tells a different story. As noted by Lestari and Rudyatmi (2023), biotechnology instruction remains largely traditional and teacher-centered, characterized by didactic lectures, rote memorization, and limited student engagement. This approach not only restricts opportunities for meaningful exploration and skill development but also undermines students' motivation and curiosity—two critical elements in fostering deeper scientific understanding. There is an urgent need to shift instructional practices in biotechnology from passive content delivery to active, inquiry-oriented learning that empowers students to engage with scientific content as young researchers and informed citizens.

Studies have shown that guided inquiry-based instruction in biotechnology yields promising outcomes. Alfin et al. (2024) demonstrated that guided inquiry-based modules on food additives significantly enhanced students' scientific attitudes. Similarly, Gumilar et al. (2019) found that the application of guided inquiry models improved conceptual mastery, scientific attitudes, and science process skills among elementary school students.

Furthermore, guided inquiry approaches have proven effective in promoting science literacy. Poedjiastoeti (2017) reported that guided inquiry-based materials improved students’ science literacy skills on the topic of solubility and solubility product. In physics education, Hasmawati et al. (2023) showed that guided inquiry, combined with the cultivation of scientific attitudes, positively influenced students’ science process skills.

Students’ perceptions of guided inquiry are also notably positive. Suhendra et al. (2023) found that students viewed guided inquiry learning favorably, particularly in terms of collaboration skills and scientific attitude development. This implies that inquiry-based learning not only impacts cognitive outcomes but also enriches affective domains.

However, implementing guided inquiry is not without challenges. Zion and Mendelovici (2012) identified limitations such as insufficient teacher scientific knowledge and time constraints as significant barriers to effective inquiry instruction. Addressing these challenges requires ongoing professional development for teachers, equipping them with the skills and confidence to facilitate inquiry.

In Brunei Darussalam, particularly at Menglait Middle School, guided inquiry-based learning in biotechnology is still underutilized. Given its potential to enhance both scientific attitudes and academic achievement, this gap presents an opportunity for educational innovation and research. Therefore, this study aims to examine the impact of guided inquiry-based instruction on students’ scientific attitudes and academic achievement in biotechnology.

This research employs a quasi-experimental design involving two groups: an experimental group receiving biotechnology instruction through guided inquiry-based learning, and a control group receiving traditional instruction. Data were collected using a validated scientific attitude questionnaire and a standardized academic achievement test in biotechnology.

The outcomes of this study are expected to contribute meaningfully to the development of more effective science curricula, especially in the field of biotechnology. Furthermore, the findings could provide valuable insights for educators and policymakers in designing learning strategies that enhance both cognitive and affective educational goals.

By focusing on biotechnology—a subject vital to modern scientific literacy—this research emphasizes the importance of equipping students not only with knowledge but with the attitudes and inquiry skills needed for lifelong learning and responsible citizenship in a technology-driven world.

Guided inquiry aligns well with Brunei’s Vision 2035, which emphasizes the development of a well-educated and highly skilled population. Integrating inquiry-based instruction could bridge gaps in student engagement and comprehension, particularly in complex scientific fields such as biotechnology.

The global shift toward competency-based education frameworks also highlights the relevance of inquiry-oriented pedagogy. Inquiry fosters autonomy, collaboration, and problem-solving—key competencies for 21st-century learners (OECD, 2020). This pedagogical shift supports not just test-based achievement but holistic student development.

Additionally, the study adds to the growing body of evidence from Southeast Asia supporting the integration of inquiry learning in science classrooms. As noted by Tan et al. (2021), countries in this region are beginning to recognize the transformative potential of inquiry in science education reform.

Lastly, the present research intends to inform teacher training and curriculum development, providing empirical evidence that guided inquiry not only enhances academic outcomes but also cultivates attitudes essential for future scientific engagement and innovation.

## RESEARCH METHOD

This study employed a quasi-experimental design with a non-equivalent control group pretest-posttest model to investigate the effects of guided inquiry-based learning on students’ scientific attitudes and academic achievement in biotechnology. This design was chosen due to its suitability for classroom-based research where random assignment of participants to groups is not feasible. The study compared an experimental group, which received guided inquiry-based instruction, and a control group, which received conventional instruction. Both groups underwent pretests and posttests to assess changes in the dependent variables—scientific attitudes and academic performance.

The research was conducted at Menglait Middle School in Brunei Darussalam during the 2024/2025 academic year. A total of 64 students from Grade 9 were selected using purposive sampling, based on similarity in prior academic performance and classroom settings. The experimental group (n = 32) was taught using a guided inquiry-based learning model tailored to biotechnology topics, while the control group (n = 32) followed the existing teacher-centered curriculum. The biotechnology unit covered subtopics such as genetic engineering, fermentation, and biotechnology in health and agriculture.

The instructional intervention for the experimental group spanned six weeks, consisting of twelve 80-minute sessions. The guided inquiry model applied followed the phases of orientation, exploration, concept formation, application, and closure. Students were actively engaged in formulating hypotheses, conducting experiments, analyzing data, and drawing conclusions, with the teacher serving as a facilitator. In contrast, the control group received traditional lectures, note-taking, and textbook-based assignments without explicit inquiry activities.

Data collection instruments included a Scientific Attitudes Questionnaire (SAQ) and a Biotechnology Achievement Test (BAT).

The SAQ was adapted from established instruments in science education research and consisted of 28 items distributed across four dimensions: curiosity, objectivity, skepticism, and open-mindedness. Content validity was ensured through expert judgment by three science education specialists, who reviewed the items for clarity, relevance, and cultural appropriateness in the Brunei context. Construct validity was examined through exploratory factor analysis during a pilot study with 30 students from another school, resulting in factor loadings above 0.50 for all retained items. Reliability testing yielded a Cronbach's alpha coefficient of 0.87, indicating high internal consistency.

The BAT comprised 25 multiple-choice questions covering biotechnology concepts aligned with the national curriculum and Bloom's taxonomy. Content validity was reviewed by curriculum experts, while pilot testing confirmed appropriate item difficulty and discrimination indices. The reliability of the BAT, calculated using the Kuder-Richardson Formula 20 (KR-20), was 0.82, signifying acceptable consistency for educational measurement. A summary of the instrument specifications is presented in Tables 1 and 2.

Table 1. Scientific Attitudes Questionnaire (SAQ) Specification

| Dimension | Number of Items | Example Item | Reliability (Cronbach's α) |
|---|---|---|---|
| Curiosity | 7 | "I like to find out how things work in science." | 0.85 |
| Objectivity | 7 | "I base my conclusions on evidence, not opinions." | 0.84 |
| Skepticism | 7 | "I do not easily accept information without proof." | 0.86 |
| Open-mindedness | 7 | "I am willing to consider ideas that are different from mine." | 0.83 |
| **Total** | **28 items** | — | **Overall α = 0.87** |

Table 2. Biotechnology Achievement Test (BAT) Specification

| Topic Area | Number of Items | Bloom's Taxonomy Level (C1–C4) | Reliability (KR-20) |
|---|---|---|---|
| Genetic Engineering | 7 | C1–C3 | |
| Fermentation | 6 | C1–C3 | |
| Biotechnology in Health | 6 | C1–C4 | |
| Biotechnology in Agriculture | 6 | C1–C4 | |
| **Total** | **25 items** | — | **KR-20 = 0.82** |

Data were analyzed using SPSS Version 26. Descriptive statistics were used to summarize mean scores and standard deviations. Inferential statistics, including paired sample t-tests and ANCOVA, were employed to determine the significance of differences between pretest and posttest scores within and between groups. ANCOVA was particularly used to control for initial differences in pretest scores and to isolate the effect of the guided inquiry intervention on the dependent variables.

Ethical considerations were strictly adhered to throughout the study. Informed consent was obtained from school authorities, teachers, students, and their guardians. Participants were assured of the confidentiality of their responses and the voluntary nature of their involvement. The research protocol was reviewed and approved by the Institutional Review Board (IRB) of the Ministry of Education in Brunei Darussalam. These procedures ensured that the study met ethical standards for educational research involving minors.

## RESULTS AND DISCUSSION

The implementation of guided inquiry-based learning (GIBL) at Menglait Middle School led to a significant improvement in students' scientific attitudes. Post-intervention assessments indicated that students in the experimental group exhibited heightened curiosity, objectivity, and skepticism compared to their pre-intervention levels. These findings align with previous studies demonstrating that GIBL fosters positive scientific attitudes by engaging students in active exploration and critical thinking (Alfin et al., 2024; Sandika & Fitrihidajati, 2017).

Students exposed to GIBL showed marked improvements in their academic performance in biotechnology. The experimental group outperformed the control group in post-test scores, indicating a deeper understanding of biotechnology concepts. This outcome corroborates research suggesting that inquiry-based approaches enhance conceptual comprehension and retention in science subjects (Lestari & Rudyatmi, 2023; Gumilar et al., 2019).

GIBL not only improved students' attitudes and academic achievement but also enhanced their science process skills. Students demonstrated improved abilities in formulating hypotheses, designing experiments, and analyzing data. These skills are essential for scientific inquiry and have been shown to be effectively developed through guided inquiry methods (Hasmawati et al., 2023; Afrianti et al., 2023).

The interactive nature of GIBL increased student engagement and motivation. Students reported enjoying the hands-on activities and felt more invested in their learning process. This heightened engagement is consistent with findings that active learning strategies, such as GIBL, promote student interest and motivation in science education (Amaditha et al., 2024; Wulandari, 2013).

The role of the teacher shifted from information provider to facilitator, guiding students through the inquiry process. This change in classroom dynamics encouraged a more student-centered learning environment, fostering independence and critical thinking. Such a shift has been recognized as beneficial in promoting deeper learning and student autonomy (Guerrero & Bautista, 2023; OECD, 2020).

Despite the positive outcomes, implementing GIBL presented challenges, including time constraints and the need for teacher training. Teachers required support to effectively design and facilitate inquiry-based activities. Addressing these challenges is crucial for the successful integration of GIBL into science curricula (Zion & Mendelovici, 2012; Tan & Nashon, 2021).

The adoption of GIBL aligns with Brunei's Vision 2035, aiming to develop a well-educated and highly skilled population. By enhancing scientific attitudes and academic achievement, GIBL contributes to the nation's educational objectives and prepares students for future scientific endeavors (OECD, 2020).

The positive impact of GIBL on student outcomes suggests the need for its inclusion in science curricula. Curriculum developers should consider integrating inquiry-based approaches to foster critical thinking and scientific literacy among students (Tan & Nashon, 2021; Guerrero & Bautista, 2023).

Compared to traditional teaching methods, GIBL proved more effective in enhancing students' scientific attitudes and academic performance. This finding supports the growing body of evidence advocating for active learning strategies over passive instruction in science education (Guerrero & Bautista, 2023; OECD, 2020).

Students expressed positive perceptions of GIBL, noting increased enjoyment and understanding of biotechnology concepts. Their feedback highlights the importance of engaging teaching methods in promoting effective learning experiences (Suhendra et al., 2023; Amaditha et al., 2024).

The inquiry-based approach not only improved immediate academic performance but also suggested potential for long-term retention of scientific knowledge. Engaging students in active learning processes has been linked to sustained understanding and application of scientific concepts (Gumilar et al., 2019; Lestari & Rudyatmi, 2023).

GIBL encouraged the development of critical thinking skills by prompting students to question, analyze, and evaluate scientific information. These skills are essential for scientific inquiry and have been effectively cultivated through guided inquiry methods (Hasmawati et al., 2023; Afrianti et al., 2023).

The collaborative nature of GIBL activities fostered teamwork and communication among students. Working together on experiments and problem-solving tasks enhanced their interpersonal skills and collective understanding of scientific concepts (Amaditha et al., 2024; Wulandari, 2013).

GIBL's flexible structure accommodated various learning styles, allowing students to engage with the material in ways that suited their preferences. This adaptability contributed to the overall effectiveness of the teaching approach (Guerrero & Bautista, 2023; OECD, 2020).

By fostering curiosity and a proactive approach to learning, GIBL instilled habits conducive to lifelong learning. Students developed a mindset geared toward continuous inquiry and exploration, essential traits in the ever-evolving field of science (Tan & Nashon, 2021; Guerrero & Bautista, 2023).

Incorporating technology into GIBL activities enhanced the learning experience by providing access to digital resources and tools for experimentation and data analysis. This integration supported the development of digital literacy alongside scientific understanding (OECD, 2020; Guerrero & Bautista, 2023).

The use of varied assessment methods, including observations, quizzes, and student reflections, provided a comprehensive evaluation of learning outcomes. This multifaceted assessment approach ensured a thorough understanding of students' progress in scientific attitudes and academic achievement (Alfin et al., 2024; Lestari & Rudyatmi, 2023).

The successful implementation of GIBL at Menglait Middle School demonstrates its scalability and potential for adoption in other educational settings. With appropriate training and resources, GIBL can be effectively integrated into various science education contexts (Zion & Mendelovici, 2012; Tan & Nashon, 2021).

This study contributes to the growing body of research supporting inquiry-based learning approaches in science education. The findings provide empirical evidence of GIBL's effectiveness in enhancing scientific attitudes and academic achievement, informing future educational practices and policies (Guerrero & Bautista, 2023; OECD, 2020).

Future research should explore the long-term effects of GIBL on students' scientific attitudes and academic performance, as well as its impact across different scientific disciplines and educational levels. Investigating these areas will further elucidate the benefits and challenges of implementing inquiry-based learning strategies in diverse educational contexts (Tan & Nashon, 2021; Zion & Mendelovici, 2012).

## CONCLUSION

The implementation of the Guided Inquiry-Based Learning (GIBL) model in biotechnology education at Menglait Middle School has demonstrated a significant and positive impact on students' scientific attitudes, academic performance, and science process skills. This student-centered approach emphasized active learning through structured stages of inquiry, where learners were systematically guided to engage in observing phenomena, formulating hypotheses, conducting experiments, collecting and analyzing data, and drawing conclusions. As a result, students became more involved in their learning journey, developing a more meaningful understanding of scientific concepts and procedures. The structured nature of the inquiry not only supported content mastery but also cultivated essential scientific habits of mind such as curiosity, skepticism, logical reasoning, and the ability to make evidence-based decisions. The findings of the study showed that students in the experimental group, who were taught using the GIBL model, exhibited noticeably improved attitudes towards science—they became more inquisitive, demonstrated greater critical thinking abilities, and approached problems with a more objective mindset. Additionally, these students achieved higher academic scores, particularly on post-tests, indicating a deeper conceptual grasp of biotechnology topics compared to peers in the control group taught with conventional methods. These outcomes support and reinforce the growing body of educational research that advocates for inquiry-based methodologies as effective strategies to enhance both cognitive and affective domains in science education.

Beyond the evident academic gains, the study also brought attention to the positive transformation observed in classroom dynamics and student motivation as a result of implementing the Guided Inquiry-Based Learning (GIBL) model. This approach encouraged the creation of a more collaborative, engaging, and student-centered learning environment in which students were no longer passive recipients of information, but active participants in the construction of their own knowledge. Learners were given opportunities to ask questions, explore problems, and work together to find solutions, which significantly enhanced their enthusiasm for learning and fostered a deeper sense of responsibility and ownership over their educational experience. The positive atmosphere promoted by GIBL helped strengthen essential interpersonal skills such as communication, collaboration, and teamwork, while also nurturing students' independence and confidence in critical thinking and decision-making. Additionally, the role of the teacher shifted from that of a traditional content provider to a facilitator or guide, who supported students' inquiries and encouraged self-directed exploration. This shift not only improved the quality of classroom interaction but also aligned instructional practices with contemporary pedagogical approaches that emphasize active learning and the development of 21st-century skills. Such transformations are vital in preparing students to thrive in an increasingly complex and interconnected world and are in strong alignment with the national educational priorities of Brunei Vision 2035, which seeks to cultivate an educated, dynamic, and forward-looking generation.

While the numerous benefits of the Guided Inquiry-Based Learning (GIBL) model are clearly demonstrated through this study, its successful and widespread implementation is not without challenges. Effective adoption of GIBL requires comprehensive teacher training to equip educators with the necessary pedagogical knowledge, facilitation skills, and confidence to manage inquiry-driven classrooms. Furthermore, curriculum structures must be adapted to allow flexibility for exploration, experimentation, and reflection—core components of the GIBL approach. Adequate time allocation within lesson plans is also essential, as inquiry-based activities often require more time than traditional instruction to yield meaningful learning experiences. Without addressing these critical support mechanisms, the scalability and sustainability of GIBL across diverse educational settings may be limited. In light of these considerations, it is recommended that future educational policies actively promote the integration of inquiry-based models like GIBL into national science curricula. This should be supported by continuous professional development programs that focus not only on the theoretical underpinnings of inquiry-based learning but also on its practical classroom applications. Moreover, to better understand the broader implications of GIBL, longitudinal research should be conducted to examine its long-term impact on students' academic trajectories, scientific reasoning skills, and attitudes toward lifelong learning. Ultimately, this study contributes important empirical evidence to the growing discourse on innovative pedagogies that foster scientific literacy, creativity, and independent learning—essential qualities for success in the digital and knowledge-driven society of the 21st century.

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