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Guided inquiry improves undergraduate students' psychomotor skills in gram staining practicum

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Abstract

Gram staining of bacteria is an important practical material in Microbiology and Parasitology courses as part of Basic Nursing Science. This technique is widely used for the initial identification of pathogenic microorganisms. However, observations indicate that some students have not mastered the Gram staining technique optimally, leading to difficulties in interpreting microscopic findings. Until now, practical learning has been dominated by demonstration and one way instruction methods, so that the development of students' psychomotor skills has not been optimal. This study aims to evaluate the effectiveness of the guided inquiry method in improving the psychomotor skills of nursing students in Gram staining practical. The study used a quasi experimental design with a pretest–posttest control group design. The research subjects were students of the Nursing Study Program, semester II of the 2025/2026 Academic Year, consisting of two classes, namely the guided inquiry class (70 students) and the control class (72 students). Psychomotor skill data were analyzed based on the difference between posttest and pretest scores. The difference in psychomotor skill improvement between the two groups was analyzed using the Independent Samples t-test at a significance level of 0.05. The results showed a significant difference in the difference in psychomotor skill scores between the guided inquiry group with a higher average score then control group. This indicates that guided inquiry learning is effective in improving students' psychomotor skills in Gram staining practicums.

Abstrak. *Pewarnaan Gram pada bakteri merupakan materi praktikum penting dalam mata kuliah Mikrobiologi dan Parasitologi sebagai bagian dari Ilmu Keperawatan Dasar. This technique is widely used for the initial identification of pathogenic microorganisms, so mastering these psychomotor skills is essential for students to ensure the accuracy of clinical diagnoses. Namun, pengamatan menunjukkan bahwa sebagian mahasiswa belum menguasai teknik pewarnaan Gram secara optimal, sehingga menimbulkan kesulitan dalam menafsirkan temuan mikroskopis. Hingga saat ini, pembelajaran praktikum masih didominasi oleh metode demonstrasi dan pengajaran satu arah, sehingga pengembangan keterampilan psikomotorik mahasiswa belum optimal. Penelitian ini bertujuan untuk mengevaluasi efektivitas metode inquiry terarah dalam meningkatkan keterampilan psikomotor mahasiswa keperawatan pada praktikum pewarnaan Gram. Penelitian ini menggunakan desain kuasi-eksperimental dengan desain pretest–posttest kelompok kontrol. Subjek penelitian adalah mahasiswa Program Studi Keperawatan, semester II Tahun Akademik 2025/2026, yang terdiri dari dua kelas, yaitu kelas inquiry terarah (70 mahasiswa) dan kelas kontrol (72 mahasiswa). Data keterampilan psikomotor dianalisis berdasarkan selisih skor posttest dan pretest. Perbedaan peningkatan keterampilan psikomotor antara kedua kelompok dianalisis menggunakan Uji-t Sampel Independen pada tingkat signifikansi 0,05. Hasil menunjukkan adanya perbedaan yang signifikan pada selisih skor keterampilan psikomotor antara kelompok pembelajaran inquiry terarah dengan skor rata-rata yang lebih tinggi dibandingkan kelompok kontrol. Hal ini menunjukkan bahwa pembelajaran berbasis inquiry terarah efektif dalam meningkatkan keterampilan psikomotorik siswa pada praktikum pewarnaan Gram.*

A. Introduction

The microbiology laboratory course is a key component of nursing education. This course provides students with the foundation needed to support evidence based clinical decision making. The ability to perform proper Gram staining of bacteria is one of the core competencies that nursing students must master. According to Durrant et al. (2017) and colleagues, microbiology education is essential in nursing practice because it strengthens students' understanding of infectious microorganisms and improves their ability to apply laboratory skills in clinical settings.

Gram staining of bacteria is a topic of study in Microbiology and Parasitology, which are part of the Basic Sciences of Nursing. Gram staining of bacteria is the most important staining technique in microbiology and is the first step in identifying a bacterial species (Paray et al., 2023). Guidelines, microbiology lecture and laboratory courses are essential components in nursing education because they provide students with fundamental competencies related to microorganism identification, infection control, and laboratory diagnostic skills (Norman-McKay & Committee, 2018). A lack of understanding of microbiology can lead to procedural errors, an increased risk of cross infection, and inaccuracies in interpreting laboratory results (Lee & Jeong, 2022). Therefore, mastering the Gram staining technique requires not only conceptual understanding but also strong psychomotor skills, ranging from preparing the specimen to interpreting the results under a microscope.

However, based on previous researchers' observations, some students have not yet mastered the Gram staining technique therefore, they are unable to accurately interpret the staining results under a microscope. Several technical errors were still identified, such as inaccuracies in reagent application, suboptimal fixation techniques, and improper timing during the decolorization process. This resulted in suboptimal specimen staining quality, making it difficult for students to correctly identify bacterial groups microscopically. Therefore, a more active and practice based learning approach is needed so that students can improve their psychomotor skills, the accuracy of their interpretation of results, and their laboratory competencies in microbiological examinations.

One alternative teaching method that can be applied is the guided inquiry method in the Gram staining laboratory exercise. This framework systematically transitions students from passive technical replication to structured, problem solving execution. This approach aligns with the findings of (Ami et al., 2021) who reported that integrating guided inquiry into laboratory sessions significantly improves students' psychomotor performance. Consequently, implementing this model in microbiology education facilitates the development of procedural precision and technical autonomy required for complex laboratory tasks.

The guided inquiry method provides students with the opportunity to discover information either with or without assistance so that they can explore and investigate the issue logically and critically. This method can also stimulate students curiosity to conduct experiments, thereby helping them better understand the learning concepts (Sujana, 2020).

Learning using the guided inquiry model can encourage student engagement and develop critical thinking skills (Nisa et al., 2018). Critical thinking skills are closely related to activity based and problem solving laboratory work. This aligns with the research by Sadita et al. (2025) which shows that the guided inquiry learning model has a significant effect on increasing students learning activity and critical thinking skills. Critical thinking skills are related to conceptual understanding and impact psychomotor skills.

Research by Algiani et al. (2023) shows that the implementation of a guided inquiry learning model combined with a self regulated learning approach significantly enhances students creativity and creative thinking skills in biology instruction compared to a standard inquiry model. This confirms that a learning structure that encourages active student engagement while providing support for self regulated learning can enhance higher order thinking skills, including creativity and reflective abilities regarding the learning process.

In the Gram staining laboratory exercise, these findings are relevant because psychomotor skills in the laboratory depend not only on technical proficiency but also on student's ability to plan, control, and evaluate their work steps independently (Almira et al., 2023; Lipson & Gair, 2011). Therefore, the combination of inquiry based learning and self directed learning has the potential to help students not only master laboratory procedures but also critically analyze, evaluate, and refine their techniques through reflective practice (Gupta et al., 2015).

The inquiry based approach in health education is understood not only as a problem solving strategy but also as a reflective process that fosters meaningful learning and the development of professional competencies (Gilardi & Lozza, 2009). Inquiry based learning in medical education enhances student engagement through reflection on effective learning practices, thereby supporting the development of scientific thinking skills (Sandars & Murdoch-Eaton, 2017). This can strengthen the application of guided inquiry methods in the context of nursing education, which emphasizes laboratory based learning.

In addition to the field of health, the inquiry based approach can enhance the quality of science education. Multilevel inquiry fosters more meaningful learning by engaging students at various levels of active participation in laboratory practice (Anwar, 2020). Furthermore, inquiry based laboratory learning has also been shown to promote investigative learning through student engagement. Students are involved in the design, implementation, and analysis of experiments in microbiology and biochemistry laboratory sessions (Periyannan, 2019). Meanwhile, Bachhawat et al. (2020) found that inquiry based learning that emphasizes learning through error can strengthen students reflective abilities, although its implementation poses.

However, no specific study has examined the application of the guided inquiry method to nursing students' psychomotor skills in Gram staining of bacteria. This highlights the need for research evaluating the effectiveness of the guided inquiry method in improving nursing students' technical skills in the microbiology laboratory. Although previous literature has examined guided inquiry in science education in general, its empirical application within the specific context of nursing laboratories has not yet been extensively explored. This study examines the application of the guided inquiry method in Gram staining training, given that psychomotor skills in this procedure are closely linked to clinical safety and diagnostic accuracy. The article evaluates the importance of procedural precision in nursing education materials, particularly regarding aseptic techniques and decolorization timing. These findings provide a scholarly contribution by demonstrating how an inquiry based approach can transition routine laboratory procedures into interactive problem solving capabilities for future nurses.

B. Material and method

This study employed a quasi experimental design with a pretest posttest control group design. The study subjects were students in the Nursing Program at the Faculty of Health who were taking the Basic Nursing Science course during the second semester of the 2025/2026 academic year. The sample consisted of two classes: the Guided Inquiry class, comprising 70 students, and the control class, comprising 72 students. To establish baseline equivalence and address potential selection bias inherent in the quasi-experimental design, a pretest was administered to both groups prior to the intervention. The mean pretest score for the Guided Inquiry class was 55.42 ± 7.93, while the control class obtained a mean score of 52.36 ± 7.80. An independent samples t-test showed that this small difference was not statistically significant, p = 0.735. This statistically confirms that both groups possessed a comparable level of baseline knowledge before the implementation of the treatment, ensuring the equivalence of the participants at the onset of the study.

The research procedure consists of three stages: preparation, implementation, and evaluation. The flowchart of the research procedure is shown in Figure 1.

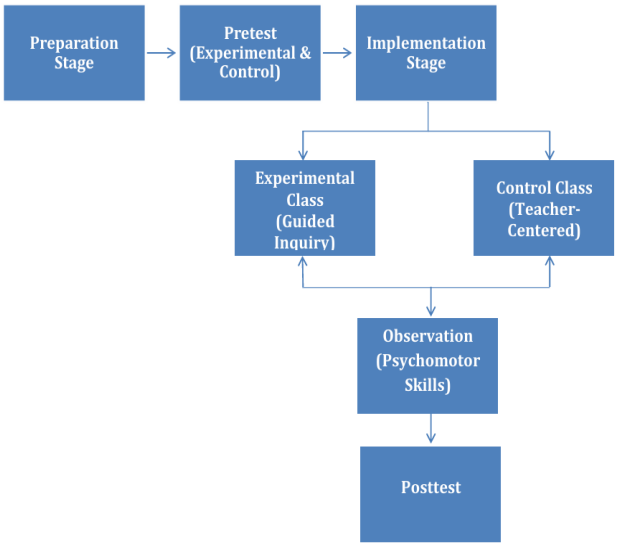

Figure 1 Flowchart of the research procedure

As shown in Figure 1, the initial phase of the study began with a preparation stage involving the development of guided inquiry based learning materials tailored to the Gram staining laboratory exercise. In addition, the researcher prepared a research instrument in the form of a psychomotor skills observation sheet. Prior to the instruction, students in the experimental and control classes were administered a psychomotor skills pretest through initial observation while performing basic laboratory exercises in accordance with standard laboratory procedures.

During the implementation phase, the experimental class participated in a laboratory session using the guided inquiry method. The activity began with an orientation and problem formulation, during which the instructor explained the learning objectives and presented contextual problems related to the Gram staining laboratory session. Students were then guided to formulate investigative questions, develop preliminary hypotheses, and plan the laboratory steps based on their prior knowledge, with limited guidance from the instructor. Next, students conducted the lab independently in small groups, making observations, recording experimental data, and were assessed using a psychomotor skills observation sheet. After the lab was completed, students analyzed the data, discussed their observations, and drew conclusions, with the instructor acting as a facilitator during the discussion and reflection process.

Meanwhile, instruction in the control class was conducted using a teacher centered approach. The instructor first explained the concepts and objectives of the lab session, then demonstrated the procedures. Students carried out the lab session by following the instructions provided, observing the results, and recording data. The instructor presented the conclusions. Psychomotor observations were conducted based on predetermined indicators. After the entire learning sequence was completed, students in both groups were given a posttest.

The instrument used in this study was a structured psychomotor skills observation sheet, designed as a performance assessment rubric to evaluate students' technical skills during the Gram staining procedure. Psychomotor skill data were analyzed based on the difference between post-test and pre-test scores. A normality test was conducted on the score difference data for each group using the Shapiro Wilk test. Next, a test for homogeneity of variances was conducted using Levene's test. Differences in the improvement of psychomotor skills between the experimental group and the control group were analyzed using an independent samples t-test at a significance level of 0.05 (Pallant, 2020).

C. Results and discussion

A normality test was conducted on the difference between post-test and pre-test scores (Δ) in the guided inquiry group and the control group as a prerequisite for analysis using parametric tests (see Table 1). The normality test was performed using the Shapiro-Wilk test. The analysis results showed that the significance value for the guided inquiry group was 0.338 and for the control group was 0.683. All significance values were greater than 0.05 ($p > 0.05$), so it can be concluded that the data on the difference between post-test and pre-test scores in both groups were normally distributed. Next, the data were tested using an independent samples t-test.

Based on the results of the homogeneity test in Table 2, the significance value of Levene's Test for the psychomotor ability variable (Δ Post-Pre) was 0.715. This significance value is greater than 0.05 ($p > 0.05$), so it can be concluded that the students' psychomotor ability data are homogeneous.

Table 1 Normality test for the guided inquiry and control groups

Groups	Sig.	Description
Guided inquiry	.338	Normal
Control	.683	Normal

Tabel 2 Homogeneity Test

Variabel (Δ Post-Pre)	Sig.	Description
Psychomotor skills	.715	Homogen

Tabel 3 Results of the independent samples t-test: Difference in psychomotor ability scores (Δ)

Groups	n	Mean a ± SD	p
Guided inquiry	70	25.74 ± 9.43	< 0,001
Control	72	17.94 ± 8.79	

Description: Δ = difference between post-test and pre-test scores $p < 0.05$ indicates a significant difference

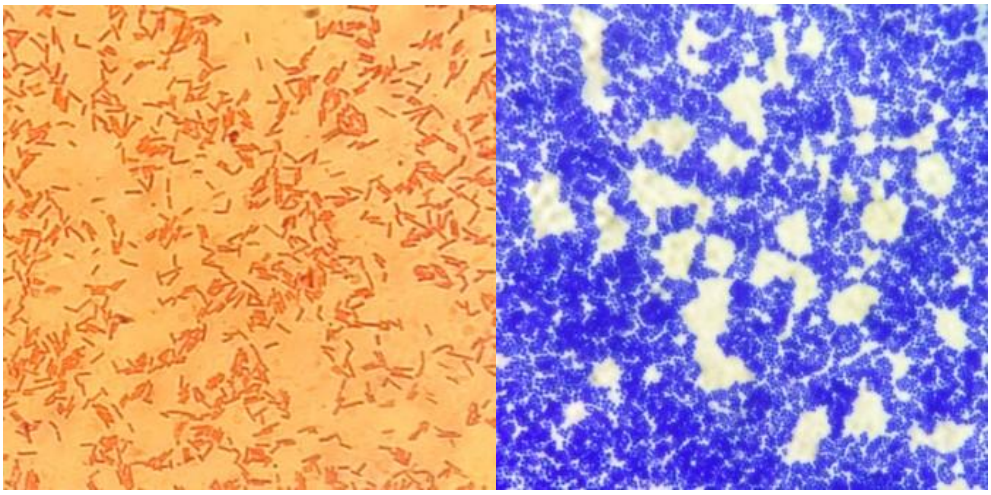

Figure 2 Microscopic observation results of Gram-negative (left) and Gram-positive (right) bacteria

The results of the independent samples t-test on the difference in post-test and pre-test scores (Δ) between the guided inquiry class and the control group are presented in Table 3. The guided inquiry group consisted of 70 respondents, while the control group consisted of 72 respondents. The analysis results show that the average difference in learning outcome scores in the guided inquiry group was 25.74 ± 9.43, while in the control group it was 17.94 ± 8.79. The Independent Samples t-test showed a significance level of $p < 0.001$. This value indicates a significant difference in learning outcome scores between the guided inquiry group and the control group. The application of guided inquiry was able to improve student's psychomotor skills in the bacterial Gram staining laboratory practice.

Figure 2 shows that Gram staining results reveal distinct characteristics between Gram-positive and Gram-negative bacteria under a microscope. Gram staining results that distinguish between Gram-positive and Gram-negative bacteria can also be linked to students' psychomotor skills in performing microbiology laboratory procedures. Gram-positive bacteria appear purple, while Gram-negative bacteria appear pink, indicating that the staining procedure was performed correctly and in accordance with the established steps. The cell walls of Gram-positive bacteria are able to retain this complex after the decolorization process, causing them to appear purple, whereas Gram-negative bacteria lose their color after this treatment and appear pink (Coico, 2006). Clear slide results demonstrate students' psychomotor skills in accurately performing each step of the Gram staining process, from slide preparation, fixation, reagent application, and washing, to decolorization techniques and microscopic observation of the bacteria.

The results of the study indicate that the implementation of the inquiry based learning method significantly improves student's psychomotor skills in Gram staining laboratory sessions compared to conventional, teacher centered learning methods. These findings suggest that inquiry based learning makes a tangible contribution to the development of students laboratory skills, particularly in laboratory activities that require precision, motor coordination, and procedural consistency (Sulawanti et al., 2019).

The effectiveness of the guided inquiry model lies in its capacity to engage students actively. Instead of adhering strictly to prescriptive procedures, learners are guided to independently discover solutions, construct understanding, and analyze outcomes, while instructors function as facilitators (Sii et al., 2017). In line with Demaria et al. (2019) this inquiry based approach provides space for students to actively engage, reflect on laboratory outcomes, and continuously correct technical errors through direct experience and self evaluation. In the context of the Gram staining laboratory, this inquiry process specifically manifests during critical procedural steps. For instance, instead of being passively told the exact duration, students must critically evaluate the dekolorization timing by observing the runoff color of the alcohol, allowing them to self correct and prevent over or under decolorization. Furthermore, through guided exploration, students actively problem solve specimen preparation and fixation to ensure the bacterial smear is neither too thick nor washed away during rinsing. This active engagement extends to microscope handling, where students independently optimize illumination and finefocus to accurately interpret and classify the morphology of Gram-positive or Gram-negative bacteria.

Gram staining is a fundamental technique in microbiology that requires a high level of concentration. The success of this procedure depends heavily on the accuracy of the step by step procedure, specimen handling techniques, and the use of the correct reagents. The use of inquiry based learning provides a clear learning structure while still encouraging students to explore and reflect on the technique. This aligns with the findings of (Adauyah & Aznam, 2024) who state that guided inquiry learning is effective in improving science process skills through direct and active learning experiences.

The implementation of inquiry based learning in the Gram staining lab had a significant impact on students' psychomotor skills. Students were encouraged to participate more actively in the lab, thereby optimizing the skills they acquired. Students were directly involved in designing the lab procedures and in the microscopic observation of bacteria. This is consistent with the findings of Sulawanti et al. (2019) who stated that the application of a laboratory based inquiry learning model has a significant effect on students' psychomotor skills.

Through this learning process, students are actively involved in every stage of the laboratory activity, from understanding procedures and making observations to evaluating the results obtained. This active involvement enables students to develop their laboratory skills in a more systematic and focused manner. This finding aligns with research conducted by Septyowaty and Syafii (2023) who reported that the application of the guided inquiry model can improve student's psychomotor skills and interest in learning physics. In addition, the use of guided inquiry in this study serves as a bridge between theory and visualization, helping students learn about structural biochemistry in an active, focused, and more in depth manner (Roche Allred et al., 2017).

By the final observation, the students' psychomotor improvement in observing bacteria microscopically was higher in the guided inquiry group ($\Delta = 25.74 \pm 9.43$) than in the control group ($\Delta = 17.94 \pm 8.79$; $p < 0.001$). This higher proficiency enabled them to accurately classify bacteria as Gram-positive or Gram-negative. Gram staining is a

fundamental technique in microbiology, students are expected not only to follow proper procedures but also to interpret the results obtained. These findings align with Mursali et al. (2024), who stated that the guided inquiry model can enhance students' science process skills and conceptual understanding. These science process skills include the ability to use tools, conduct experiments, and interpret results, which are directly related to psychomotor ability indicators. The improvement in students' psychomotor abilities in this study reinforces that guided inquiry is effective in developing scientific skills comprehensively.

Guided inquiry based learning effectively enhances students' technical independence in the laboratory. This is evident in the students' ability to carry out each stage of the lab experiment with a high degree of independence and systematic precision. These outcomes corroborate the findings of Saefi et al. (2023), which indicated that inquiry based laboratory instruction substantially improves students' technical proficiency and procedural accuracy in performing microbiological techniques.

Systematic thinking is also cultivated through Guided Inquiry learning, which influences the precision and accuracy of laboratory procedures. The findings of this study are consistent with those of Purwati et al. (2020), who stated that a guided inquiry model based on open ended problem solving can improve student learning outcomes. Although that study was conducted in the context of mathematics learning, the basic principles of guided inquiry which emphasize student engagement, problem solving, and systematic thinking are relevant to the implementation of the Gram staining laboratory procedure. In this study, the guided inquiry approach not only improved conceptual understanding but also enhanced student's psychomotor skills in performing laboratory procedures accurately and systematically.

Inquiry based learning can enhance students deeper and more enduring conceptual understanding (Pikoli et al., 2025; Sinon et al., 2022). The implementation of guided inquiry learning through the experimental method has a positive effect on students conceptual understanding due to their active involvement in the learning process, such as problem formulation, conducting experiments, and data analysis (Şen, 2024; Sinon et al., 2022). This approach encourages students to actively explore concepts and relate them to laboratory experiences, thereby making learning more meaningful (Pikoli et al., 2025).

The improvement in student's psychomotor skills during the Gram staining laboratory session indicates that the implementation of guided inquiry learning can support the mastery of technical laboratory skills. Through this approach, students not only follow procedural steps but also actively engage in the process of observation, analysis, and reflection on the results of the laboratory session. This active involvement enables students to understand the purpose of each step, making the execution of laboratory techniques more systematic and accurate. Although this study did not measure students' critical thinking skills, previous research has shown that inquiry based learning has the potential to foster the development of critical thinking skills, which ultimately supports student learning outcomes. This aligns with the findings of Rambe et al. (2020) who reported that a guided inquiry learning model combined with critical thinking skills has a positive impact on learning outcomes. Therefore, the guided inquiry approach not only has the potential to enhance conceptual understanding but also supports the development of student's laboratory skills.

Students who learn through guided inquiry demonstrate greater proficiency in systematically following the steps of the Gram staining procedure, from slide preparation and fixation to the application of primary and wash reagents, and finally the drying stage. The accuracy of the sequence and consistency of timing at each stage are crucial aspects of successful Gram staining thus, inquiry based learning that requires students to understand the rationale behind each step contributes to increased procedural accuracy. This aligns with the view that students active involvement in designing and carrying out laboratory procedures can strengthen their mastery of procedural skills and motor coordination in a sustainable manner (Demaria et al., 2019; Sulawanti et al., 2019).

In addition to the accuracy of procedural steps, guided inquiry based learning also has a significant impact on improving technical skills and the ability to interpret Gram stain results. Students become more skilled at handling specimens, controlling pressure during washing, and adjusting the focus and lighting of the microscope during observation. These technical skills support student's ability to accurately interpret observation results, including distinguishing Gram-positive and Gram-negative bacteria based on cell color and morphology. Inquiry based learning encourages students to relate observation results to the theoretical principles of Gram staining, ensuring that the psychomotor skills developed are not merely mechanical but integrated with analytical and reflective abilities. These support the assertion that laboratory based inquiry based learning can enhance both technical skills and the quality of laboratory result interpretation through direct experience and a structured reflection process (Ratnasari, 2016; Saefi et al., 2023; Sinon et al., 2022).

Overall, the results of this study indicate that guided inquiry based learning is a more effective approach than conventional methods in improving students psychomotor skills during Gram staining laboratory sessions. This method supports conceptual understanding and thinking processes and guided inquiry plays a role in reducing learning achievement gaps (Walker & Warfa, 2017). The implementation of

an inquiry based approach has proven crucial in bridging the gap between theoretical knowledge and practical demands in hospitals. Through an inquiry based learning model, new nursing graduates can actively internalize the signs of a patient's clinical deterioration, which in turn enhances their clinical reasoning skills in real world situations (Chen et al., 2025). This study has implications for improving teaching strategies in the laboratory. Specifically, this approach can support the development of psychomotor skills among nursing graduates and technical proficiency in clinical practice in the field of microbiology.

D. Conclusion

The application of the guided inquiry learning method has proven effective in improving students' psychomotor skills during Gram staining laboratory sessions. This approach encourages active participation, enabling students to perform staining techniques more systematically and meticulously, in accordance with established standard procedures. In practical terms, these findings highlight the importance of microbiology instructors and lab assistants as facilitators who guide the problem solving process when students encounter technical difficulties during staining. This study has limitations in its research design and scope, as it is limited to a single laboratory topic. Therefore, further research is recommended to test the effectiveness of this method in various other microbiological techniques.

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