Bioeduca: Journal of Biology Education
Vol. 8 (2) 2026: 178 – 190
ISSN: 2715-7490 (online); 2714-8009 (printed)

Student's Science Process Skilss on Poster-Mediated Research-Based Learning Model in Biotechnology Topics

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Abstract: The low level of students' research-based skills, reflected in teacher-centered learning and limited opportunities for direct scientific engagement, motivated this study. This research aimed to examine the effect of poster-assisted Research-Based Learning (RBL) and describe students' science process skills in learning microbial utilization for biotechnology. A quantitative approach with a quasi-experimental Posttest-Only Nonequivalent Control Group Design was employed. The population comprised all tenth-grade students at SMA Batik 2 Surakarta in the 2025/2026 academic year, with samples selected through cluster random sampling. Data were collected through tests, observations, and documentation. The primary instrument was a validated and reliable science process skills posttest using the Rasch model through Winsteps software. Data were analyzed using Levene's test, Shapiro-Wilk test, one-way ANOVA, and post-hoc LSD test. The results showed a significant effect of poster-assisted RBL on science process skills ($p < 0.001$), with the highest performance across most indicators. Thus, poster-assisted RBL is an effective alternative for improving science process skills in biology learning.

Keywords: Biology learning; Biotechnology; Poster Media; RBL; Science Process Skills.

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Submitted : May 25, 2026
Received in revised form : August 31, 2026
Accepted : September 15, 2026

Published by:
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Introduction

Biology learning in the 21st century requires students not only to master scientific concepts but also to develop scientific skills that support critical thinking, problem-solving, and evidence-based decision-making (Hariandi et al., 2023). One of the essential competencies that should be fostered is science process skills (SPS), which encompass the abilities to observe, classify, interpret data, formulate hypotheses, conduct experiments, and communicate scientific findings (Hariandi et al., 2023). Science process skills are regarded as a fundamental component of science education because they enable students to acquire knowledge through systematic scientific experiences rather than merely memorizing facts or concepts (Angelia et al., 2022). Studies conducted over the last decade have demonstrated that student-centered learning approaches significantly enhance scientific reasoning and student engagement in learning activities (Dini et al., 2025). However, science instruction in schools frequently remains teacher-centered and primarily emphasizes verbal knowledge transfer, resulting in suboptimal development of students' science process skills (Susiani et al., 2019). This condition indicates that strengthening science process skills remains an essential priority in biology learning at the secondary education level.

Recent developments in science education emphasize the need for instructional models that integrate scientific activities into students' learning experiences. Research-Based Learning (RBL) engages students actively in the research process, from problem identification and hypothesis formulation to data collection and reporting (Supit & Winardi, 2024). Grounded in constructivism, RBL promotes knowledge construction through authentic learning experiences (Riastuti et al., 2025). By involving students directly in scientific activities, RBL provides opportunities for them to develop scientific skills through systematic investigation and evidence-based learning. Thus, RBL is highly relevant to biology education, which requires not only conceptual understanding but also the ability to apply scientific processes in investigating biological phenomena.

Several studies have demonstrated the potential of RBL to enhance students' science process skills across different educational contexts. Usmeldi (2016), for example, developed and implemented a research-based physics learning model for senior high school students at SMA N 2 Padang, Indonesia, and reported that its implementation effectively improved students' scientific processing skills. In a microbiology course, Rahmayanti et al. (2018) investigated 107 Biology students at Universitas Negeri Medan, Indonesia, and found that RBL significantly influenced students' science process skills, with students receiving RBL achieving higher posttest scores than those receiving direct learning. Similarly, Khumraksa & Burachat (2022) implemented RBL with fourth-grade elementary school students and found that the learning activities supported the development of scientific questioning and experimental skills. Rizki et al. (2022), through a literature review of research-based learning in elementary education, also reported that research-based learning can improve students' science process skills. Collectively, these findings indicate that RBL can support the development of science process skills by engaging students in scientific inquiry and research activities.

In the context of biology education, the topic of microbial utilization in biotechnology represents a subject that requires both conceptual understanding and scientific skills. Modern biotechnology emphasizes not only theoretical comprehension of the utilization of microorganisms to produce enzymes, antibiotics, and other bioactive metabolites but also an understanding of research-based and experimental approaches involving these microorganisms (Nazwari et al., 2025). Instruction on this topic often presents challenges because the concepts involved are abstract, complex, and difficult to comprehend when taught primarily through lectures and textbooks or textbook-based explanations (Susilawati, S. & Neneng, 2016). Recent studies have demonstrated that project-based and research-oriented learning approaches can enhance science process skills while simultaneously helping students understand biotechnology concepts in a more practical and applicable manner (Putri et al., 2024). Consequently, biotechnology instruction requires strategies that connect abstract concepts with authentic experiences through contextualized investigative activities. These challenges highlight the importance of instructional innovation that enables students to directly experience scientific processes through learning activities involving the application of microorganisms.

One authentic context that can be integrated into biotechnology learning is the use of endophytic bacteria as a research-based learning object. Endophytic bacteria are microorganisms that inhabit plant tissues without causing disease and are known to possess broad application potential in agriculture, health sciences, and biotechnology (Mametja et al., 2025). Recent research has demonstrated that endophytic bacteria can produce bioactive metabolites that support plant health and serve as biocontrol agents and plant growth promoters (Fadiji et al., 2025). Scientific activities involving the observation, isolation, and characterization of endophytic bacteria provide students with more concrete learning experiences compared to purely theoretical instruction (Oliveira & Bonito, 2023). Students' engagement in these activities may facilitate a deeper understanding of microbial utilization concepts through direct inquiry-based experiences. Accordingly, endophytic bacteria offer strong potential as an authentic context for fostering students' science process skills.

In addition to the selection of instructional models and learning contexts, visual learning media also play a crucial role in supporting effective science education. Posters are visual instructional media capable of presenting information systematically, communicatively, and attractively, thereby helping students understand concepts in a more structured manner. Within research-based learning environments, posters function not only as information delivery tools but also as scientific communication media that enable students to organize, summarize, and present their investigative findings (Leone & French, 2022). Previous studies have shown that poster-based learning can enhance students' abilities to organize information, think critically, and communicate scientific ideas effectively (Prasetyo et al., 2025). Presenting research findings in poster form also encourages students to visually interpret data systematically, thereby supporting several indicators of science process skills. Therefore, integrating posters into research-based learning is considered capable of strengthening the effectiveness of science instruction.

Although previous studies have confirmed the effectiveness of Research-Based Learning in improving science process skills, several research gaps remain evident. Most earlier studies primarily examined the general impact of RBL on critical thinking or academic achievement without integrating specific and authentic learning contexts within biotechnology instruction (Daryanes & Sayuti, 2023). Studies concerning poster utilization have generally focused on improving conceptual understanding or learning motivation without combining posters with research-oriented instructional approaches (Utami et al., 2024). Furthermore, investigations concerning endophytic bacteria have largely been conducted within microbiology and agricultural disciplines rather than being explored as contextual learning materials in school biology education (Mametja et al., 2025). Limited empirical research has directly integrated Research-Based Learning, poster-mediated instruction, and the context of endophytic bacteria within a single instructional design aimed at improving students' science process skills in biotechnology, particularly microbial utilization topics. This gap highlights the need for research that combines these three components as a contextualized and authentic instructional innovation.

Based on preliminary observations, students continue to experience difficulties in understanding microbial utilization topics when instruction relies primarily on verbal explanations and textbooks. Students tend to demonstrate better understanding when they are given opportunities to conduct observations, collect data, and draw conclusions through direct experiences. These findings indicate the need for instructional approaches that actively engage students in scientific investigation. The integration of poster-mediated Research-Based Learning with the context of endophytic bacteria is considered capable of providing more concrete learning experiences while simultaneously strengthening students' science process skills. Such authentic and contextualized instruction is expected to improve students' abilities to observe, interpret findings, formulate conclusions, and communicate scientific results systematically. Therefore, this instructional approach has strong potential to address challenges in biology learning, particularly in microbial utilization topics.

Based on the current educational context and the identified research gap, this study aims to determine the effect of poster-mediated Research-Based Learning on students' science process skills in microbial utilization for biotechnology topics. This research is intended to provide empirical evidence regarding the effectiveness of integrating research-based instruction, poster media, and the authentic context of endophytic bacteria into biology learning. The findings are expected to broaden the literature on research-oriented biology instruction while offering an innovative, contextualized, and meaningful instructional alternative. Furthermore, this study is expected to contribute to educational practice by emphasizing not only conceptual mastery but also the development of science process skills as essential competencies for the 21st century. Thus, this research is anticipated to provide both theoretical and practical contributions to the advancement of biology education at the secondary school level.

Methods

This study employed a quantitative approach using a quasi-experimental method to investigate the effect of Research-Based Learning (RBL) and poster-mediated Research-Based Learning on students' science process skills. The research adopted a Posttest-Only Nonequivalent Control Group Design, consisting of one control class and two experimental classes. The control class received conventional instruction, whereas the first experimental class received Research-Based Learning and the second experimental class received poster-mediated Research-Based Learning. The study was conducted at SMA Batik 2 Surakarta, Central Java, Indonesia, during the 2025/2026 academic year. The population comprised all tenth-grade students enrolled in biology courses, totaling 155 students. Sampling was carried out using a cluster random sampling technique following prerequisite testing of normality and homogeneity based on students' biology semester examination scores (Penilaian Akhir Semester/PAS). Based on the sampling procedure, Class X.3 was assigned as the control group, while Classes X.4 and X.5 served as experimental groups.

Research data were collected through documentation, testing, and classroom observation techniques to obtain comprehensive information regarding instructional implementation and students' science process skills. Documentation included lesson plans, student worksheets, instructional posters, attendance records, classroom activity photographs, scoring rubrics, posttest results, and statistical outputs. The primary research instrument consisted of a posttest containing ten items developed according to science process skill indicators, including observing, classifying, interpreting, predicting, questioning, hypothesizing, planning investigations, using tools and materials, applying concepts, and communicating findings. In addition, observation sheets were used to monitor the implementation fidelity of the Research-Based Learning model during classroom instruction. Prior to implementation, the instrument underwent content and construct validation using expert judgment and Rasch model analysis through Winsteps version 5.11.0 software. Reliability testing was conducted using Cronbach's Alpha, Person Reliability, and Item Reliability to ensure the consistency and suitability of the instrument for research purposes.

Table 1.
KPS question indicators.

Question Number	KPS Indicators	Formulation of Question Indicators
1	Observing/ observing	Presented with images of the results of the antibacterial activity test of the endophytic bacterial isolate *Sargassum sp.*, students are asked to observe the test results and identify the facts from the observations that indicate the presence of antibacterial activity.
2	Grouping/ classification	Presented with images of the results of the antibacterial activity test of several endophyte isolates, students were asked to group the isolates based on the presence or absence of antibacterial activity using the presence of clear zones as the basis for classification.
3	Interpreting/ interpretation	Presented with observation data from antibacterial activity tests of several endophytic isolates, students were asked to interpret the relationship between differences in the growth response of the test bacteria and the ability of the endophytic isolates, identify patterns in the observation results, and draw conclusions regarding the potential for antibacterial activity.
4	Forecasting/ prediction	Presented with a case of the absence of antibiotics and the inappropriate use of antibiotics, students were asked to predict the possible impact on the healing of the disease and the possible consequences of inappropriate use of antibiotics.
5	Ask a question	Presented with images of antibacterial test results against *E. coli* with varying concentrations of 10 µg/mL, 20 µg/mL, 40 µg/mL, and 80 µg/mL as well as differences in the diameter of the inhibition zone, students are asked to ask relevant scientific questions to investigate the factors that influence differences in antibacterial activity.
6	Hypothesize	Presented with information from research journal results regarding five endophytic bacterial isolates from burubuas leaves and the results of the catalase test, students were asked to put forward two hypotheses that could explain why not all endophytic bacteria produce the catalase enzyme.
7	Planning research/ experiments	Presented with information regarding research on endophytic bacteria producing the enzyme catalase, students are asked to plan a simple research to prove the existence of bacteria producing the enzyme catalase by determining the tools and materials, research variables, data obtained, and research steps.
8	Using tools/ materials	Presented with images and information on the sterilization stages in endophytic bacterial isolation research, students are asked to identify the tools and materials used and explain how to use these tools in the sterilization process.
9	Applying the concept	Presented with information on research results regarding endophytic bacteria producing the enzyme catalase and the role of the enzyme catalase in health, students are asked to apply the concept of the function of the enzyme catalase to explain the benefits of screening or selecting endophytic bacteria producing the enzyme catalase in the health sector.
10	Communicate	A table of research results is presented regarding the characteristics and ability of endophytic bacterial isolates to produce catalase enzymes. Students are asked to communicate the research results by briefly explaining the information obtained based on the data in the table.

The collected data were analyzed using descriptive and inferential statistical procedures. Prior to hypothesis testing, normality and homogeneity tests were conducted using Jamovi software through the Shapiro–Wilk test and Levene's Test at a significance level of 0.05. When statistical assumptions were fulfilled, hypothesis testing was performed using One-Way Analysis of Variance (One-Way ANOVA) to examine differences in science process skills among the instructional groups. Significant findings were followed by Tukey's Honestly Significant Difference (HSD) post hoc analysis to determine pairwise differences between groups. However, when normality or homogeneity assumptions were not satisfied, the Kruskal–Wallis test was employed as a non-parametric alternative. All analyses were conducted at a 95% confidence level to determine the significance of differences among treatment groups.

Results & Discussion

The descriptive results in Table 1 show differences in students' science process skills among the three groups, with the control class obtaining the lowest mean score (71.1), followed by the RBL class (78.3), while the poster-mediated RBL class achieved the highest mean score (87.7). The higher scores in the RBL groups are consistent with previous research. Khumraksa and Ruksakit (2019) reported that research-based instruction improved students' science process skills by actively involving them in scientific investigation and learning activities. Similarly, Sangkasame and Phusee-orn (2025) found that research-based learning enhanced students' integrated science process skills, particularly through activities that required students to engage in scientific inquiry. The higher performance of the poster-mediated RBL group also suggests that visual media may provide additional support for organizing information and facilitating students' understanding during learning activities. This finding is in line with Primadini (2019), who reported that the use of learning media could support the development of students' science process skills. Therefore, the higher score in the present study may be attributed to the combination of research-oriented activities in RBL and visual support provided by the poster.

Table 2.

Descriptive Statistics of Students' Science Process Skills Posttest Scores.

Statistical Results	**Class**		
	Control	**Experiment 1**	**Experiment 2**
N	25	24	34
Missing	9	10	0
Mean	71,1	78,3	87,7
Median	70,0	78,8	87,5
Standard deviation	7,81	7,43	8,42
Minimum	57,5	65,0	72,5
Maxium	85,0	90,0	100

To further examine the distribution of students' performance, posttest achievement across science process skill indicators was analyzed and is summarized in Table 2. Experimental Class 2 showed consistently higher percentages in most indicators, particularly hypothesizing (93%), communicating (92%), interpreting (91%), and classifying (90%). The improvement of these indicators indicates that poster-mediated RBL provided opportunities for students to engage in observation, interpretation, communication, and inquiry processes more intensively than conventional instruction. This finding is consistent with Suantara and Susilaningsih (2022), who reported that guided inquiry learning improved students' science process skills through active involvement in inquiry activities. Similarly, Idul and Caro (2022) found that process-oriented guided inquiry learning improved students' science process skills compared with conventional learning. More recently, Diata Cruz and Lagura (2026) reported through a systematic literature review that inquiry-based learning generally has a positive effect on students' basic and integrated science process skills. These findings support the present result that integrating research-oriented activities with visual learning support can provide students with greater opportunities to practice various science process skills.

Interestingly, Experimental Class 1 demonstrated slightly higher performance in concept application (81%) than Experimental Class 2 (79%), suggesting that students focusing solely on inquiry activities without poster preparation may have allocated more attention to conceptual application. This finding indicates that the use of visual media does not necessarily produce higher achievement in every science process skill indicator. The effectiveness of learning media may depend on how the media are integrated with learning activities and the characteristics of the skills being developed. Baharuddin et al. (2023) emphasized that learning media should be appropriately integrated with science process skills and learning content to support students' understanding. Nevertheless, the overall findings confirm that Experimental Class 2 outperformed the other groups across most science process skill dimensions. These findings imply that combining inquiry-based activities with visual learning support contributes to a more comprehensive development of scientific competencies, although its contribution may vary across individual science process skill indicators.

Table 3.

Percentage of Science Process Skill Indicators.

Indicator	Class (%)		
	Control	Experiment 1	Experiment 2
Observing	68	75	82
Grouping/Classifying	77	78	90
Interpreting	70	84	91
Predicting	70	73	82
Asking questions	70	78	89
Hypothesizing	72	81	93
Planning research or experiments	71	84	90

Indicator	Class (%)		
	Control	Experiment 1	Experiment 2
Using tools/materials	67	73	88
Applying concepts	72	81	79
Communicating	74	75	92

Before hypothesis testing, prerequisite analyses were conducted to determine whether the data fulfilled parametric assumptions. The results of the Shapiro–Wilk normality test indicated significance values greater than 0.05 across all groups, while Levene's Test confirmed homogeneity of variance with a significance value of 0.694, indicating that the data met the assumptions for parametric testing. Therefore, a One-Way Analysis of Variance (One-Way ANOVA) was performed to examine differences in students' science process skills among the three instructional groups. The ANOVA analysis demonstrated a statistically significant difference among groups ($p < 0.001$), indicating that the instructional interventions produced different effects on students' science process skills. These findings confirm that the integration of Research-Based Learning and poster-mediated Research-Based Learning significantly influenced students' learning performance compared to conventional instruction. These findings are in line with Diata Cruz and Lagura (2026), who reported that inquiry-based learning methods positively influenced students' science process skills through active engagement in scientific inquiry activities. The statistical evidence supports the assumption that inquiry-oriented and visually supported learning environments are more effective in fostering science process skills.

Table 4.

One-Way ANOVA Hypothesis Test Results of Science Process Skills.

Data	Dependent variable	Sig.	Criteria	Result
Posttest Scoret	Science Process Skills	< 0,001	Sig. < 0,05	H_1 accepted

To identify which instructional groups significantly differed, a Tukey HSD post hoc analysis was conducted, and the findings are presented in Table 3. The results indicated statistically significant differences among all group pairs, including Experimental Class 1 and Experimental Class 2 ($p < 0.001$), Experimental Class 1 and the control group ($p = 0.006$), and Experimental Class 2 and the control group ($p < 0.001$). The largest mean difference was observed between Experimental Class 2 and the control group (16.62 points), demonstrating the strongest effect of poster-mediated Research-Based Learning on science process skills. These findings suggest that the inclusion of posters provided additional support beyond inquiry-based instruction by enhancing scientific communication, information organization, and conceptual visualization. Consequently, the combination of research-based inquiry and visual media appears more effective than inquiry activities alone in promoting science process skills development.

Table 5.
Tukey HSD Post Hoc Comparison.

Group Comparison		*Mean difference*	Sig.	Result
Experiment 1	Experiment 2	-9, 39	< 0,001	Significantly different
Experiment 1	Control	7, 23	0, 006	Significantly different
Experiment 2	Control	16, 62	< 0,001	Significantly different

The findings of this study are consistent with constructivist learning theory, which emphasizes that knowledge is actively constructed through direct learning experiences. Students in Experimental Class 2 not only participated in inquiry activities but also synthesized and communicated their findings through poster preparation, thereby strengthening their scientific understanding and communication abilities. These findings are in agreement with previous studies reporting that inquiry- and research-based instruction enhances science process skills through active student engagement in scientific investigation (Bahtiar & Dukomalamo, 2019). Furthermore, the findings extend prior research by demonstrating that poster integration strengthens the effectiveness of Research-Based Learning, particularly in communication, interpretation, and hypothesis formulation skills. A notable strength of this study lies in the combination of authentic inquiry activities and visual instructional support, which created a more interactive and meaningful learning environment. However, because this study was conducted within a limited school context and focused on biotechnology topics, broader implementation in other science subjects and educational settings is recommended for future studies.

Conclusion & Recommendation

This study concluded that poster-assisted Research-Based Learning (RBL) significantly improved students' science process skills in microbial biotechnology, as indicated by the One-Way ANOVA result ($p < 0.001$). The Tukey HSD test further showed the largest difference between Experimental Class 2 and the control class (mean difference = 16.62; $p < 0.001$). These findings indicate that integrating poster media into RBL is more effective than conventional instruction and RBL without supporting media, as it facilitates students' engagement in observation, investigation, discussion, and scientific communication. Thus, poster-assisted RBL can serve as an effective instructional alternative for strengthening science process skills in biology learning.

Future research should examine the application of poster-assisted RBL across different biology topics, educational levels, and broader samples. Further studies may also investigate its effects on learning outcomes, critical thinking, creativity, and scientific literacy, as well as compare it with other innovative learning models and supporting media, including interactive videos, infographics, and digital technologies.

Acknowledgment

The authors would like to express sincere gratitude to all parties who contributed to the implementation of this research. Special appreciation is extended to the school principal, biology teachers, and students of SMA Batik 2 Surakarta for their support, cooperation, and active participation throughout the research process. The authors also sincerely thank academic supervisors and validators who provided valuable guidance, constructive suggestions, and feedback during the preparation and completion of this study. Appreciation is further addressed to all individuals and institutions who supported the implementation of learning activities, data collection, and research administration. The cooperation and contributions provided by various parties played an important role in ensuring the successful completion of this study. Therefore, the authors highly appreciate all forms of support that contributed to the accomplishment of this research.

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