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The Effectiveness of STEM-Based LKPD on Grade X Students' Science Process Skills in Bacteria Material

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ABSTRACT

Bacteria content in senior high school biology is often taught in an abstract manner, limiting students' opportunities to engage in scientific investigation and develop science process skills. This study examined the effect of using STEM-based student worksheets (LKPD) on Grade X students' science process skills in learning bacteria. The research was conducted at SMAN 26 Bandung using a quantitative approach with a non-equivalent control group quasi-experimental design. The sample consisted of 92 students, with 46 students in the experimental class and 46 students in the control class. Data were collected through pretests and posttests and were analysed using the Shapiro–Wilk normality test, Levene's homogeneity test, N-gain analysis, and an independent-samples t-test. The results showed that the experimental class achieved a higher N-gain score (0.6041, moderate category) than the control class (0.0435, low category). The mean posttest score of the experimental class (79.52) was also higher than that of the control class (76.26). These findings indicate that the use of STEM-based LKPD had a positive effect on students' science process skills in bacteria learning.

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Introduction

The rapid development of science and technology in the era of the Industrial Revolution 4.0 requires education to prepare students with 21st-century competencies so that they can adapt to complex and changing demands. In science education, these competencies are not limited to conceptual understanding but also include critical thinking, creativity, collaboration, and communication, which are closely related to students' ability to engage in scientific inquiry (Osman et al., 2022; Azma et al., 2022). For this reason, science learning needs to facilitate the development of science process skills, such as observing, formulating questions, collecting data, analysing evidence, and drawing conclusions systematically (Saepurokhman et al., 2025).

In biology learning, science process skills are essential because they help students build understanding through direct investigation rather than through memorisation alone. These skills include observing, classifying, measuring, interpreting data, formulating hypotheses, conducting experiments, and communicating findings. Through such processes, students can develop a more meaningful understanding of biological concepts and a stronger scientific mindset. However, biology instruction in schools still often tends to be teacher-centred, which limits students' opportunities to actively participate in scientific activities, particularly when learning abstract topics (Purwanto et al., 2023).

One topic that frequently presents this challenge is bacteria. In school biology, bacteria are often taught theoretically, so students may find it difficult to relate the concepts to observable phenomena. As a result, students' science process skills may not be optimally developed, particularly in observation, data analysis, and evidence-based conclusion drawing. This condition indicates the need for learning materials that can guide students to engage more actively in scientific investigation.

One potential instructional support is the use of student worksheets (LKPD). When designed appropriately, LKPD can structure learning activities, guide students through inquiry processes, and provide opportunities for active engagement in observing, analysing, and communicating scientific findings. In this context, the STEM (Science, Technology, Engineering, and Mathematics) approach is relevant because it encourages students to learn through problem solving, investigation, and the integration of scientific concepts with practical applications. Previous studies have shown that STEM-based learning can support student engagement and strengthen scientific and higher-order thinking skills (Mu'minah, 2020; So et al., 2019).

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Nevertheless, studies examining the use of STEM-based worksheets in bacteria learning, particularly those focusing on students' science process skills, are still limited. Existing research has more commonly discussed STEM learning in general science contexts or has emphasised conceptual understanding and critical thinking, while fewer studies have specifically examined how STEM-based LKPD can support science process skills in learning bacteria through contextual practical activities. Therefore, a more focused investigation is needed to examine whether the use of STEM-based LKPD can contribute to better science process skill outcomes in this topic.

Based on this background, this study aimed to examine the effect of using STEM-based LKPD on Grade X students' science process skills in learning bacteria. The findings are expected to contribute empirical evidence regarding the use of STEM-based worksheets as an instructional alternative to support more active and meaningful biology learning.

Methods

This study employed a quantitative approach using a non-equivalent control group quasi-experimental design. The study involved an experimental class and a control class. Both groups were administered a pretest before the intervention and a posttest after the intervention to examine differences in students' science process skills after the learning treatment. The experimental class was taught using STEM-based LKPD, whereas the control class was taught using conventional LKPD in learning bacteria material. This design was selected because the study was conducted in intact school classes rather than through random assignment of individual students.

The study was conducted at SMAN 26 Bandung. The population consisted of 92 Grade X students from two classes, namely class X.9 and class X.10, with 46 students in each class. The sample comprised all students in the two classes. The sampling technique used in this study was purposive sampling. Class X.9 was assigned as the experimental class and class X.10 as the control class based on the teacher's recommendation. From the twelve available classes, these two classes were selected because their initial abilities were considered relatively similar, the number of students was nearly equal, and the classroom characteristics were not substantially different. The similarity of students' initial ability was further examined through the pretest results.

The intervention was implemented in two meetings, with each meeting lasting 135 minutes. Both the experimental and control classes were taught by the same teacher. In the experimental class, students learned bacteria material using STEM-based LKPD designed to guide them through structured scientific activities. In the control class, students learned the same topic using conventional LKPD. The main difference between the two groups was the learning approach embedded in the worksheet and classroom activities. The STEM-based LKPD in the experimental class emphasized project-based practical work through STEM stages, whereas the conventional LKPD in the control class focused more on material explanation, discussion, and question-solving activities.

In the experimental class, learning began with introductory activities in the form of activation of prior knowledge and explanation of the learning objectives. In the core activity, students carried out project-based practicum activities covering STEM stages, namely observing phenomena (science), using simple tools or media (technology), designing and conducting experiments (engineering), and analysing observational data (mathematics). After completing the practicum, students discussed and presented their results. The lesson ended with conclusion drawing, reflection, and the administration of the posttest.

In the control class, learning was conducted using a scientific approach through the stages of observing, questioning, gathering information, reasoning, and communicating. The activities were more focused on the use of conventional LKPD, including identification of bacterial characteristics, reproduction, and roles, followed by teacher explanation, discussion, and exercise completion. The lesson was then concluded with summary activities and evaluation.

Data were collected using test and non-test techniques. The test instrument consisted of a pretest and a posttest used to assess students' science process skills before and after the intervention. The science process skills assessed in this study included 11 indicators, measured using 15 essay items. In addition, a non-test instrument in the form of an observation sheet was used to assess the implementation of learning activities during the intervention. The observation sheet consisted of a learning implementation checklist with a scoring scale of 0–4 and was used to evaluate teacher and student activities during the learning process.

The collected data were analysed using descriptive and inferential statistics. Normality testing was conducted using the Shapiro–Wilk test, and homogeneity testing was conducted using Levene's test. Because the data met the assumptions of normality and homogeneity, differences between groups were analysed using an independent-samples t-test. Students' improvement was also analysed using N-gain. The significance level for all inferential analyses was set at 0.05.

Results and Discussion

The findings of this study were obtained from the administration of pretests and posttests in the experimental and control classes. The analysis was conducted to examine differences in students' science process skills after the implementation of learning using STEM-based LKPD in the experimental group and conventional LKPD in the control group. Before comparing the outcomes of the two groups, prerequisite tests were conducted to determine whether the data met the assumptions required for parametric analysis.

Normality Test of Pretest and Posttest Data

As shown in Table 1, the results of the Shapiro–Wilk test indicated that the pretest and posttest scores in both the control and experimental classes were normally distributed. In the control class, the pretest score had a significance value of 0.161 and the posttest score had a significance value of 0.136. In the experimental class, the significance values were 0.253 for the pretest and 0.708 for the posttest. Since all significance values were greater than 0.05, the data were considered to meet the assumption of normality. This result indicates that the score distributions in both groups were sufficiently normal to justify further parametric analysis.

Table 1. Results of Normality Tests for *Pretests* and *Posttests* in the Control Class and Experimental Class

	Shapiro-Wilk		
Class	**Statistic**	**df**	**Sig.**
Pre-test A (Control)	.964	46	.161
Posttest A (Control)	.962	46	.136
Pre-test B (Experimental)	.969	46	.253
Posttest B (Experimental)	.982	46	.708

Homogeneity Test of Pretest and Posttest Data

The homogeneity test results are presented in Table 2. Based on Levene's test, the significance value was 0.378, with additional significance values of 0.383, 0.384, and 0.379 for the median-based, adjusted median-based, and trimmed mean-based calculations, respectively. Because all of these values were above 0.05, the variance of the science process skills scores in the two classes was considered homogeneous. Thus, the assumption of equal variance between groups was satisfied.

Table 2. Results of the Homogeneity Test

Results	Levene Statistic	df1	df2	Sig.
Mean (Based on Mean)	.783	1	.90	.378
Median	.767	1	.90	.383
Median and adjusted df	.767	1	.83.851	.384
Based on trimmed mean	.782	1	.90	.379

Improvement in Students' Science Process Skills

The improvement in students' science process skills after the intervention is shown in Table 3. The control class obtained an N-gain score of 0.0435, which falls into the low category, whereas the experimental class obtained an N-gain score of 0.6041, which falls into the moderate category. This pattern suggests that students who learned using STEM-based LKPD experienced a greater increase in science process skills than those who learned using conventional LKPD. Although the increase in the experimental class was not in the high category, the difference between the two groups indicates that the STEM-based worksheet was associated with a more meaningful improvement in students' performance.

Table 3. Results of the N-gain test

Class	N-Gain Score	Description
Control	0.0435	Low
Experimental	0.6041	Moderate

Comparison of Posttest Performance Between Groups

The comparison of posttest scores is presented in Table 4. The control class had a mean posttest score of 76.26, whereas the experimental class had a higher mean score of 79.52. The standard deviation was 8.442 in the control class and 7.061 in the experimental class, indicating that the distribution of scores in both groups was relatively comparable, although the experimental class showed slightly less variation. Based on these data, the experimental group demonstrated better posttest performance than the control group after the implementation of STEM-based LKPD. Based on the descriptive statistics presented in Table 4, the experimental group showed better posttest performance than the control group after the implementation of STEM-based LKPD.

Table 4. Descriptive Statistics of Posttest Scores in the Control and Experimental Classes

	Class	N	Mean	Std. Deviation	Std. Error Mean
Score	Posttest Control Class	46	76.26	8.442	1,245
	Experimental Class Posttest	46	79.52	7,061	1,041

The overall pattern across Tables 1–4 shows a consistent result. The prerequisite assumptions for parametric testing were fulfilled, the experimental class achieved a higher mean posttest score, and the increase in learning outcomes measured through N-gain was clearly greater in the experimental class than in the control class. Taken together, these findings support the interpretation that the use of STEM-based LKPD contributed positively to students' science process skills in learning bacteria. This finding is in line with previous studies reporting that STEM-based learning can support the development of science process skills by engaging students in investigation, analysis, and contextual problem solving (Thibaut et al., 2020; Rosdianto, 2019; Lestari et al., 2018).

The higher performance of the experimental class can be understood in relation to the characteristics of the learning activities embedded in STEM-based LKPD. In this study, the worksheet did not merely function as a written task sheet, but as a structured guide that directed students to engage with bacteria material through observation and data-based interpretation. Such learning conditions are relevant to the nature of science process skills, which develop more effectively when students are actively involved in inquiry-oriented activities rather than passively receiving information. Previous studies have similarly shown that STEM-oriented learning can strengthen students' scientific thinking and process skills because students are directly involved in exploration and investigation of scientific phenomena (Thibaut et al., 2020; Margot & Kettler, 2021; Lestari et al., 2018).

The N-gain result shown in Table 3 is particularly important for interpreting the educational meaning of the intervention. The low N-gain in the control class indicates that conventional worksheet-based learning produced only a very limited improvement in students' science process skills. By contrast, the moderate N-gain in the experimental class suggests that the STEM-based LKPD provided a more supportive learning structure for helping students practice scientific procedures during the lesson. This interpretation is consistent with studies showing that STEM-based learning can improve science process skills when students are given opportunities to investigate, discuss, and solve problems in a contextual manner (Rosdianto, 2019; Dwiningsih et al., 2024; Lestari et al., 2018).

The difference in posttest means presented in Table 4 also supports this interpretation. Although the numerical difference between the two groups was not very large, the higher score in the experimental class indicates a more favorable learning outcome after the intervention. In the context of classroom-based quasi-experimental research, such a pattern remains meaningful because the learning was conducted in naturally existing classes rather than under tightly controlled laboratory conditions. Therefore, the result can be interpreted as evidence that STEM-based LKPD may serve as a useful instructional support for improving science process skills in bacteria learning, while still avoiding excessive generalization beyond the context of this study. This more cautious interpretation is important because the available data support a positive association, but not a broad claim about universal effectiveness across all settings.

Practical Activity Results Using STEM-Based LKPD

The practical component of the study provided additional contextual support for the quantitative findings. In this activity, students collected environmental samples from several school locations and observed bacterial colony growth on simple culture media. The observed results are shown in Figure 1, Figure 2, and Figure 3. Figure 1 presents bacterial colonies obtained from toilet-area samples, Figure 2 shows bacterial growth from a classroom desk sample, and Figure 3 displays bacterial colonies obtained from the lobby area. These figures demonstrate that the practicum enabled students to observe visible microbial growth from different environmental surfaces, thereby connecting abstract microbiology concepts with directly observable phenomena.

Figure 1. Toilet sample bacteria Round cup (female toilet) Square cup (male toilet)

Figure 2. Bacteria samples from a desk in a classroom

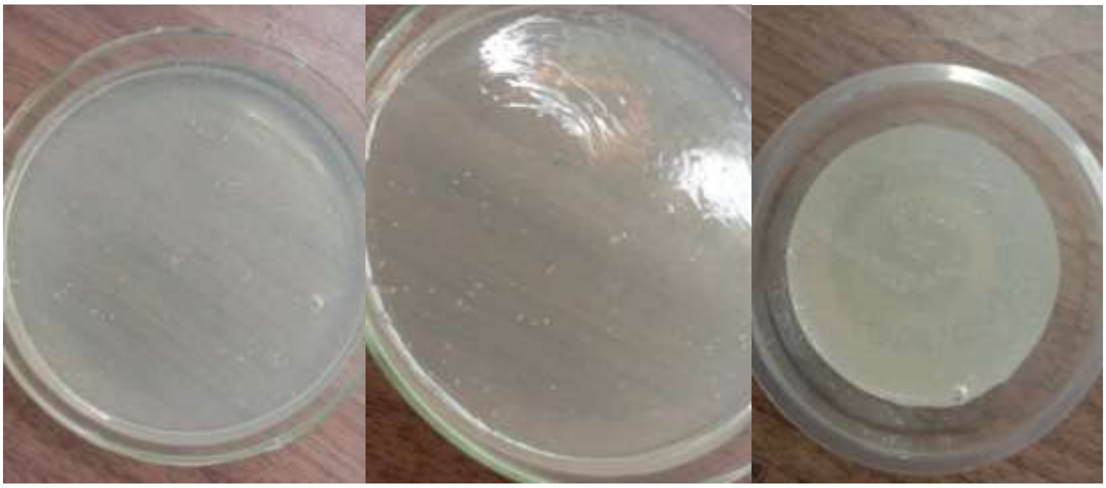

Figure 3. Bacteria samples from the lobby

The inclusion of practical observation is pedagogically relevant because bacteria are often taught as an abstract topic, making it difficult for students to connect the material with real-life contexts. Through the practicum documented in Figures 1–3, students were given the opportunity to interact with empirical evidence rather than learning bacteria only through theoretical explanation. This kind of contextual experience is compatible with the rationale of STEM-based learning, which emphasizes the integration of scientific concepts with inquiry, investigation, and interpretation of data. Prior studies have also suggested that STEM-oriented science learning can enhance students' understanding and scientific engagement when concepts are linked to authentic phenomena and hands-on activities (Alatas et al., 2021; Kelley & Knowles, 2021; Margot & Kettler, 2021).

Based on the observations represented in Figures 1–3, the practicum likely supported several dimensions of science process skills, particularly observation, classification, interpretation, and conclusion drawing. However, because the manuscript does not yet provide indicator-level quantitative data, these aspects should be discussed carefully and not as separately proven outcomes. A safer interpretation is that the practicum created learning conditions that were relevant to the development of science process skills, and that these conditions may have contributed to the better overall performance of the experimental group. This interpretation remains consistent with the quantitative findings reported in Table 3 and Table 4 while avoiding claims that are not directly measured in the available evidence.

Another important point is that the practical activity appears to have supported student engagement through direct participation in data collection and observation. The students did not only receive information from the teacher, but also interacted with samples, media, and the results of microbial growth. Such learning experiences are often associated with stronger student involvement and better scientific reasoning because learners are required to observe, compare, and interpret findings on their own. Similar tendencies have been reported in earlier STEM-related studies, which note that contextual and problem-based learning activities can strengthen engagement and support the development of science-related skills (Kelley & Knowles, 2021; Rosdianto, 2019; Dwiningsih et al., 2024). At the same time, the present study should remain cautious and avoid claiming direct measurement of engagement unless specific observational or survey evidence is later added to the manuscript.

Overall, the results indicate that the use of STEM-based LKPD was associated with better science process skill outcomes than conventional LKPD in learning bacteria. This conclusion is supported quantitatively by the higher posttest mean shown in Table 4 and the higher N-gain shown in Table 3, and contextually by the practical activities illustrated in Figures 1–3. The discussion also aligns with previous literature suggesting that STEM-based learning can support science process skills, scientific thinking, and contextual understanding when students are actively involved in investigation-oriented tasks (Thibaut et al., 2020; Margot & Kettler, 2021; Rosdianto, 2019; Zainuddin et al., 2022; Dwiningsih et al., 2024). Nevertheless, the interpretation of these findings should remain within the scope of the reported data. Since the manuscript does not yet provide complete indicator-level measurement or a full independent-samples t-test output, the claims should remain focused on the overall improvement and comparative performance of the two groups rather than on highly specific subskills or broad claims of effectiveness across contexts.

Conclusions

Based on the findings of this study, the use of STEM-based LKPD was associated with better science process skill outcomes than conventional LKPD in learning bacteria among Grade X students at SMAN 26 Bandung. This result was indicated by the higher N-gain score in the experimental class (0.6041, moderate category) compared with the control class (0.0435, low category), as well as the higher mean posttest score in the experimental class (79.52) than in the control class (76.26). These findings suggest that STEM-based LKPD can serve as a useful instructional support for facilitating students' science process skills in bacteria learning.

However, the conclusion of this study should remain limited to the findings directly reported in the manuscript. The present study supports a positive difference in overall science process skill outcomes between the two groups, but it does not provide sufficient evidence to claim product validity, detailed improvement in each specific science process skill indicator, or broad effectiveness across other contexts. Therefore, the interpretation of the findings should remain within the scope of this classroom-based quasi-experimental study.

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