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The Effect of the Discovery Learning Model on Students' Science Process Skills in Learning the Excretory System: A Quasi-Experimental Study

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Abstract: This study investigated the effect of the Discovery Learning model on students' science process skills in learning the excretory system. A quasi-experimental design with a nonequivalent control group was employed during the second semester of the 2023/2024 academic year. The participants were 54 Grade XI students at SMA Negeri 1 Pringgasela, East Lombok, West Nusa Tenggara, Indonesia, who were assigned to an experimental class and a control class. The experimental class was taught using the Discovery Learning model, whereas the control class received conventional instruction. Data were collected using an essay test administered as a pretest and posttest and an observation sheet designed to assess students' science process skills during the learning process. The observation sheet employed a five-point rating scale ranging from very poor to very good. The data were analyzed using descriptive statistics and the Mann–Whitney U test. The results revealed a statistically significant difference in science process skills between students in the experimental and control classes ($p < .001$). Observational data also showed that the experimental class achieved a mean score of 75.6, categorized as good, whereas the control class obtained a mean score of 46.3, categorized as poor. These findings indicate that the Discovery Learning model had a positive effect on students' science process skills in learning the excretory system. Therefore, Discovery Learning can be considered an effective instructional approach for promoting students' active engagement in scientific processes and developing their science process skills in biology learning.

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INTRODUCTION

Indonesia's Kurikulum Merdeka emphasizes the integration of conceptual understanding and science process skills in Biology learning. At the senior high school level, students are expected not only to understand biological concepts but also to develop scientific inquiry competencies through observing, questioning and predicting, planning and conducting investigations, processing and analyzing data, evaluating evidence, and communicating scientific findings (BSKAP, 2022). These competencies are particularly important in Biology because understanding biological phenomena requires students to engage with evidence and scientific processes rather than merely memorizing information.

Science process skills represent a set of cognitive and practical abilities that enable students to conduct scientific investigations and construct knowledge from evidence. In Biology learning, these skills include activities such as observing phenomena, classifying information, making predictions, interpreting evidence, drawing conclusions, and communicating findings. Bahtiar & Dukomalamo (2019) demonstrated that laboratory activities structured through Discovery Learning provided students with greater opportunities to develop basic science process skills than conventional laboratory instruction. Similarly, Yuliati & Susianna (2023) reported that the implementation of Discovery Learning improved students' science process skills as students became actively involved in observing, processing information, and constructing conclusions during science learning.

The development of science process skills is particularly relevant to the excretory system because this topic requires students to understand relationships among organ structures, physiological processes, and the mechanisms involved in maintaining homeostasis. Learning this topic can therefore be designed to involve observation, problem formulation, interpretation of biological information, analysis of evidence, and conclusion drawing. Previous research has also demonstrated the relevance of science process skills to learning the excretory system. Wati et al. (2023), for example, examined science process skills in the human excretory system and found significant differences between students exposed to different student-centered learning models. More recent research has also shown that inquiry- and problem-oriented instruction on the excretory system can effectively promote science process skills among senior high school students (Sa'diyah et al., 2026).

Preliminary observations and interviews conducted with teachers and students at SMA Negeri 1 Pringgasela on June 14, 2023, indicated that students' science process skills had not yet been optimally developed. Students had limited opportunities to participate in practical and investigative activities, laboratory facilities were not fully utilized during Biology instruction, and classroom activities provided relatively few opportunities for students to independently collect, analyze, and interpret scientific information. These conditions indicate a need for instructional practices that shift learning from predominantly teacher-directed activities toward learning experiences that actively involve students in scientific investigation.

One instructional model that may address this need is Discovery Learning. Rather than presenting knowledge in its final form, Discovery Learning encourages students to construct concepts through a systematic process of exploration and evidence-based reasoning. The model generally consists of six stages: stimulation, problem statement, data collection, data processing, verification, and generalization (Toy et al., 2018). These stages have a close conceptual relationship with science process skills. During stimulation and problem identification, students observe phenomena and formulate questions; during data collection and data processing, they gather, organize, and interpret evidence; and during verification and generalization, they evaluate findings and formulate conclusions. Consequently, Discovery Learning provides opportunities for students to practice scientific processes while simultaneously developing their understanding of biological concepts.

Empirical studies provide support for this relationship. Bahtiar & Dukomalamo (2019) found that Discovery Learning-based Biology laboratory practice was more effective than conventional laboratory instruction in developing students' basic science process skills. Rochmadona & Nurita (2021) also reported substantial improvement in students' science process skills following the implementation of Discovery Learning, while Yuliati & Susianna (2023) found progressive improvement in science process skills through Discovery Learning-based science instruction. In the specific context of the human excretory system, Wati et al. (2023) included Discovery Learning in a quasi-experimental comparison and reported significant differences in students' science process skills. Collectively, these studies indicate the potential of Discovery Learning to support scientific skill development; however, the cited studies were conducted at different educational levels, used different science topics, or compared Discovery Learning with another active-learning model rather than conventional instruction. Therefore, further evidence is needed regarding its effect on Grade XI students' science process skills in learning the excretory system.

Accordingly, this study aimed to examine the effect of the Discovery Learning model on Grade XI students' science process skills in learning the excretory system using a quasi-experimental nonequivalent control group design. The findings are expected to provide empirical evidence regarding the effectiveness of Discovery Learning as an instructional approach for strengthening science process skills in senior high school Biology learning.

RESEARCH METHODS

Research Design

This study employed a quantitative quasi-experimental approach using a nonequivalent pretest–posttest control group design. Two intact classes were involved: an experimental class receiving instruction through the Discovery Learning model and a control class receiving conventional instruction. Both groups completed a pretest before the intervention and a posttest after the intervention. The research design is presented in Table 1.

Table 1. Research Design

Class	Pretest	Intervention	Posttest
Experimental	O_1	X	O_2
Control	O_1	–	O_2

Note: O_1 = pretest; O_2 = posttest; X = Discovery Learning intervention.

Participants and Sampling

The population consisted of 252 Grade XI students at SMA Negeri 1 Pringgasela, East Lombok, West Nusa Tenggara, Indonesia. Two intact classes were selected through purposive sampling based on comparable academic characteristics and consideration of the Biology teacher. Grade XI-F3 was assigned as the experimental class (n = 27), whereas Grade XI-F6 served as the control class (n = 27), resulting in a total sample of 54 students. The study was conducted during the second semester of the 2023/2024 academic year.

Instructional Intervention

The experimental class was taught using the Discovery Learning model in the excretory system topic. The learning process followed six stages: stimulation, problem statement, data collection, data processing, verification, and generalization. Through these stages, students were encouraged to observe biological phenomena, identify problems, collect and analyze information, verify findings, and formulate evidence-based conclusions. The control class received conventional instruction covering the same learning topic and learning objectives.

Research Instruments

Students' science process skills were assessed using an essay test and an observation sheet. The instruments covered seven science process skill dimensions: observing, formulating hypotheses, interpreting data, planning experiments, classifying, drawing conclusions, and communicating results. The essay test was administered before the intervention as a pretest and after the intervention as a posttest. The observation sheet was used to assess students' science process skills during the learning activities and employed a five-point rating scale.

For descriptive interpretation, the observation scores were converted to a 0–100 scale and classified into five categories, as presented in Table 2.

Table 2. Categories of Science Process Skills

Score Interval	Category
$X \leq 40$	Very Poor
$40 < X \leq 55$	Poor
$55 < X \leq 70$	Fair
$70 < X \leq 85$	Good
$85 < X \leq 100$	Very Good

Source: Arikunto (2013)

Data Analysis

The data were analyzed using descriptive and inferential statistics. Descriptive statistics were used to summarize the pretest, posttest, and observation scores. Before hypothesis testing, the data were examined for normality and homogeneity of variance. Students' improvement scores were calculated by subtracting the pretest score from the posttest score. When the gain scores met the assumptions of normality and homogeneity, differences between the experimental and control groups were analyzed using an independent-samples *t*-test. When the normality assumption was not satisfied, the Mann–Whitney U test was employed. Statistical significance was determined at $p < .05$.

RESULTS AND DISCUSSION

Pretest and posttest data were obtained by administering the test before and after instruction. The data were tabulated and then analyzed using normality, homogeneity, and hypothesis tests.

Results

Descriptive Results

Students' science process skills were assessed before and after instruction in both the experimental and control classes. Descriptive statistics for the pretest and posttest scores are presented in Table 3.

Table 3. Students' Pretest and Posttest Scores

Group	Test	Highest Score	Lowest Score	Mean
Experimental (n = 27)	Pretest	42	18	28
Experimental (n = 27)	Posttest	64	40	53
Control (n = 27)	Pretest	42	18	29
Control (n = 27)	Posttest	51	31	43

As shown in Table 3, the experimental class obtained a mean pretest score of 28 and a mean posttest score of 53. Meanwhile, the control class obtained a mean pretest score of 29 and a mean posttest score of 43. The pretest means of the two groups were relatively similar, whereas the posttest mean of the experimental class was higher than that of the control class.

Normality Test

A normality test was conducted to determine whether the pretest and posttest data were normally distributed. Both the Kolmogorov–Smirnov and Shapiro–Wilk tests were used. Data were considered normally distributed when $p \geq .05$ and non-normally distributed when $p < .05$. The results are presented in Table 4.

Table 4. Results of the Normality Tests

Group and Measurement	Test	Statistic	df	p	Distribution
Experimental pretest	Kolmogorov–Smirnov	.128	27	.200	Normal
Experimental pretest	Shapiro–Wilk	.934	27	.084	Normal
Control pretest	Kolmogorov–Smirnov	.147	27	.137	Normal
Control pretest	Shapiro–Wilk	.949	27	.199	Normal
Experimental posttest	Kolmogorov–Smirnov	.235	27	.001	Non-normal
Experimental posttest	Shapiro–Wilk	.923	27	.046	Non-normal
Control posttest	Kolmogorov–Smirnov	.229	27	.001	Non-normal
Control posttest	Shapiro–Wilk	.902	27	.015	Non-normal

The results showed that the pretest scores of both groups were normally distributed because all significance values exceeded .05. In contrast, the posttest scores of both the experimental and control classes were not normally distributed because the significance values were below .05. Therefore, a nonparametric statistical test was used to compare the posttest scores between the two groups.

Homogeneity of Variance

A homogeneity-of-variance test was conducted to examine whether the variance of the data was homogeneous. The results are presented in Table 5.

Table 5. Results of the Homogeneity-of-Variance Test

Basis of Calculation	Levene's Statistic	df1	df2	p
Based on mean	2.299	3	104	.082
Based on median	2.325	3	104	.079
Based on median with adjusted df	2.325	3	101.199	.079
Based on trimmed mean	2.371	3	104	.075

Based on the mean, Levene's test produced a significance value of .082. Because the value was greater than .05, the variance of the data was considered homogeneous.

Hypothesis Testing

Because the posttest scores were not normally distributed, the difference between the experimental and control classes was analyzed using the Mann–Whitney U test. The null hypothesis was rejected when $p < .05$. The results are presented in Table 6.

Table 6. Results of the Mann–Whitney U Test

Statistic	Science Process Skills
Mann–Whitney U	93.000
Z	−4.735
Asymp. Sig. (2-tailed)	< .001

The Mann–Whitney U test yielded $U = 93.000$, $Z = -4.735$, and $p < .001$. Because the significance value was below .05, the null hypothesis was rejected. Thus, there was a statistically significant difference in science process skills between students in the experimental class taught using the Discovery Learning model and those in the control class receiving conventional instruction.

Observation-Sheet Results

Students' science process skills were also assessed using an observation sheet during the learning process. The descriptive results are presented in Table 7.

Table 7. Science Process Skill Scores Based on the Observation Sheet

Group	Measurement	Highest–Lowest Score	Mean	Category
Control (n = 27)	Pretest	70–20	38.5	Very Poor
Control (n = 27)	Posttest	80–20	46.3	Poor
Experimental (n = 27)	Pretest	80–0	48.1	Poor
Experimental (n = 27)	Posttest	100–40	75.6	Good

The observation-sheet results showed that the control class obtained a mean score of 38.5 at pretest, categorized as very poor, and 46.3 at posttest, categorized as poor. The experimental class obtained a mean score of 48.1 at pretest, categorized as poor, and 75.6 at posttest, categorized as good. Thus, after instruction, the experimental class demonstrated a higher observed level of science process skills than the control class.

Discussion

The findings showed a statistically significant difference in science process skills between the experimental and control classes, as indicated by the Mann–Whitney U test ($p < .001$). The observation data further supported this pattern. The experimental class increased from a mean score of 48.1, categorized as poor, at pretest to 75.6, categorized as good, at posttest. In comparison, the control class increased from 38.5, categorized as very poor, to 46.3, categorized as poor. These findings suggest that students who learned the excretory system through Discovery Learning demonstrated stronger science process skills after instruction than students who received conventional instruction.

The improvement observed in the experimental class can be associated with the active learning processes embedded in Discovery Learning. Rather than receiving biological concepts primarily through teacher explanation, students are required to interact with problems, gather relevant information, interpret evidence, verify their findings, and formulate conclusions. These activities provide repeated opportunities to practice key science process skills. Wulandari et al. (2018), for example, reported progressive improvement in observing, interpreting observations, hypothesizing, planning experiments, applying concepts, and communicating among Grade XI Biology students taught through Discovery Learning. Similar improvements in observing, classifying, communicating, and drawing conclusions were reported by Ciptaning et al. (2019). Waruwu et al. (2023) also found improvement in multiple science process skill indicators among senior high school students after successive cycles of Discovery Learning.

The present findings are particularly relevant to learning the excretory system because this topic requires students to connect physiological processes with evidence concerning the functions of excretory organs and mechanisms of homeostasis. Discovery-oriented activities can encourage students to move beyond memorizing organ structures and instead examine biological phenomena, identify relationships, interpret information, and formulate explanations. Khairuna et al. (2021) found that the integration of Discovery Learning and a virtual laboratory on the excretory system improved students' science process skills and learning outcomes. Nisa & Sahrir. (2023) reported progressive improvement in students' science process skill activities across meetings when Discovery Learning was implemented in Grade XI excretory-system instruction. These studies provide topic-specific support for the pattern identified in the present study.

The effectiveness of Discovery Learning in developing science process skills can also be explained by the alignment between its instructional stages and scientific investigation. During stimulation and problem identification, students are encouraged to observe phenomena and identify questions. Data-collection and data-processing activities require students to obtain, organize, compare, and interpret evidence, while verification and generalization encourage them to evaluate findings and construct evidence-based conclusions. Hayati et al. (2018) showed that guided-discovery practicum activities could develop students' abilities to observe, classify, predict, measure, conclude, and communicate. Likewise, Senisum et al. (2022) demonstrated that a student-centered guided-inquiry model produced stronger science process skills than traditional learning in senior high school Biology. These findings indicate that instructional environments emphasizing investigation and knowledge construction provide meaningful opportunities for students to repeatedly practice scientific processes.

Evidence from other inquiry-oriented Biology studies further supports this interpretation. Sinta & Agustina (2024) found that guided inquiry significantly affected high school students' science process skills and Biology learning outcomes. Inquiry-based Biology laboratory instruction has also been shown to strengthen scientific process skills by directly involving learners in investigative activities (Acarli & Dervişoğlu, 2021). In addition, inquiry-contextual learning has been reported to facilitate science process skills among senior high school students by engaging them in collecting and processing scientific information (Puspita et al., 2021), while modified free inquiry has similarly produced improvements in science process skills in Biology learning (Suryaningsih & Mu'minah, 2022). Although these approaches are not identical to Discovery Learning, they share the central principle of involving students actively in constructing knowledge through scientific investigation.

The present results are also consistent with more recent evidence across science disciplines. Bayliz et al. (2026) reported that secondary students taught through Discovery Learning achieved science process skill scores in the good category, particularly in skills associated with practical investigation, although higher-order skills such as prediction and hypothesis formulation remained more challenging. Moreover, a systematic literature review by Sofiastri et al. (2026), covering 28 studies published between 2021 and 2025, concluded that Discovery Learning consistently supported the development of science process skills across elementary, junior high, and senior high school levels by facilitating observation, experimentation, scientific reasoning, and evidence-based conclusion drawing. Thus, the advantage observed in the present experimental class is consistent with a broader body of evidence concerning the relationship between Discovery Learning and students' scientific-process development.

Developing science process skills is important not only as an instructional outcome but also because these skills contribute to students' broader understanding of Biology. Ilma et al. (2020) reported a relationship between science process skills and Biology cognitive learning outcomes among senior high school students. This relationship suggests that students who become more proficient in observing, interpreting data, formulating explanations, and communicating findings may also be better equipped to construct meaningful biological understanding. Therefore, the higher post-instruction science process skills observed in the experimental class may reflect the greater opportunities provided by Discovery Learning for students to engage cognitively and practically with the excretory-system concepts rather than learning them primarily through information transmission.

Nevertheless, the findings should be interpreted with consideration of the characteristics of the study groups. Although the test-based pretest means were relatively similar between the experimental and control classes, the observation-sheet results showed different initial levels, with means of 48.1 and 38.5, respectively. Furthermore, the classes differed in their academic characteristics, as the subject was compulsory in the experimental class but was treated as an elective specialization in the control class. Such pre-existing differences may have contributed to students' participation and responsiveness during instruction. Therefore, the significant difference observed after instruction should not be attributed exclusively to Discovery Learning without acknowledging these potential group-level influences. Future studies should employ stronger procedures for establishing baseline equivalence, larger samples, and, where possible, randomized or statistically controlled designs.

Overall, the findings indicate that Discovery Learning provides a learning environment that is compatible with the development of science process skills in the excretory-system topic. Its emphasis on problem exploration, evidence collection, data interpretation, verification, and conclusion drawing gives students opportunities to practice scientific processes as an integral part of learning Biology. The findings therefore support the use of Discovery Learning as an alternative student-centered instructional approach for strengthening science process skills, while also highlighting the need for careful instructional guidance and stronger control of initial group differences in subsequent studies.

CONCLUSION

The findings of this study indicate that the Discovery Learning model was associated with significantly stronger science process skills among Grade XI students learning the excretory system compared with conventional instruction. The Mann–Whitney U test showed a statistically significant difference between the experimental and control classes ($p < .001$). This result was supported by the observation data, in which the experimental class achieved a posttest mean score of 75.6, categorized as good, whereas the control class obtained a mean score of 46.3, categorized as poor. These findings suggest that Discovery Learning provides students with greater opportunities to engage in scientific activities such as observing, identifying problems, collecting and interpreting information, verifying evidence, and drawing conclusions. Therefore, Discovery Learning can be considered a suitable student-centered instructional approach for strengthening science process skills in learning the excretory system. However, the findings should be interpreted within the limitations of the quasi-experimental design and the pre-existing characteristics of the participating classes.

RECOMMENDATIONS

Based on the findings of this study, Biology teachers are encouraged to implement the Discovery Learning model in learning activities that require students to observe phenomena, identify problems, collect and analyze data, verify evidence, and draw conclusions. To optimize its implementation, teachers should provide structured learning worksheets, clear instructions, and appropriate guidance while maintaining students' active involvement in investigative activities. Schools should also support the implementation of Discovery Learning by improving the use of laboratory facilities and strengthening teachers' competence in facilitating student-centered and inquiry-oriented Biology learning. Future studies are recommended to involve larger samples, different Biology topics, and more diverse school contexts to examine the consistency of the effects of Discovery Learning on students' science process skills. Further research may also employ stronger experimental controls and assess individual dimensions of science process skills to determine which skills are most responsive to Discovery Learning.

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