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The Effectiveness of an E-Booklet in Enhancing Scientific Explanation Skills on the Human Immune System Topic

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Abstract This study investigates the effectiveness of an e-booklet in improving students' scientific explanation skills in the human immune system topic. A quasi-experimental design was employed, involving two groups: an experimental class using the e-booklet and a control class relying on conventional teaching methods. The study was conducted at SMAN 1 Leces Probolinggo, with 31 students in each group. Pretest and posttest assessments were used to measure scientific explanation skills, which were analyzed through statistical tests, including normality, homogeneity, t-test, and N-gain calculations. The results showed that the experimental class had a significantly higher improvement in scientific explanation skills than the control class. The N-gain score for the experimental class was 0.507, classified as moderate, whereas the control class scored 0.142, classified as low. The analysis of the three components of scientific explanation: claims, evidence, and reasoning indicated that the e-booklet was particularly effective in enhancing students' ability to construct claims and provide supporting evidence, while reasoning skills showed moderate improvement. Statistical analysis using the Mann-Whitney test confirmed a significant difference in posttest scores between the two groups ($p<0.05$), supporting the effectiveness of the e-booklet. The findings suggest that the e-booklet serves as an effective digital learning tool for fostering scientific explanation skills.

Keywords: E-Booklet, Scientific explanation skills, Human immune system topic, Science students

INTRODUCTION

Education is a deliberate and structured effort to create learning activities and environments that enable students to actively develop their potential (Amalia et al., 2025; Nuraeni et al., 2025; Wasliman, 2023). According to Law No. 20 (2003), education is defined as a conscious and planned effort to create a learning atmosphere and learning process so that students actively develop their potential in terms of personality, noble character, intelligence, spiritual strength, religious piety, self-knowledge, and skills for themselves, society, and the nation. In education, students acquire various fields of knowledge, including both worldly and religious sciences, which serve as a guide for daily life.

In the 21st century, students are expected to develop multiple competencies to prepare for future challenges (Nasution et al., 2023; González-Pérez & Ramírez-Montoya, 2022; González-Salamanca et al., 2020; Joynes et al., 2019). One of the key skills required for problem-solving is logical reasoning, as stipulated in the Regulation of the Minister of Education and Culture of Indonesia No. 21 of 2016 concerning content standards for primary and secondary education. Essential competencies include reasoning, processing, and presenting knowledge in both abstract and concrete domains. Through reasoning skills, students can formulate conclusions and construct statements based on evidence, allowing them to provide well-structured explanations of scientific concepts (Nababan, 2020; Izzah & Azizah, 2019).

One of the critical skills in scientific reasoning is scientific explanation skills. Scientific explanation skill refers to the process of thinking through a problem to find a solution based on data and strong arguments (Astutik et al., 2023; Rojikin et al., 2022; Lestari et al., 2021; Kirana et al., 2019). It involves revising one's conceptual understanding, describing, predicting, and controlling natural phenomena through reasoning. Students with strong scientific explanation skills can support their claims with evidence and logical arguments, demonstrating their understanding of scientific phenomena (Giri & Paily, 2020; De Andrade et al., 2019). Scientific explanation skill involves three core components: claim, evidence, and reasoning (Astutik et al., 2023; Rojikin et al., 2022; Lestari et al., 2021; Kirana et al., 2019). A claim is a concise statement answering a specific question. Evidence consists of scientifically valid data supporting the claim, while reasoning is the logical justification that connects the claim and evidence. These three components work together to form a complete and scientifically sound explanation.

Scientific explanation skills are particularly crucial in biology education (Karlina & Alberida, 2021), especially in understanding complex topics such as the human immune system (Fakhriah et al., 2022). This subject requires students to integrate knowledge of structure and function, making it difficult for them to visualize and comprehend without appropriate instructional support. Previous studies indicate that the human immune system is a challenging topic for students due to its abstract and dynamic nature. The complexity of this topic makes it essential to provide students with structured learning materials that enhance comprehension and facilitate the development of scientific reasoning skills.

However, research findings suggest that Indonesian students' scientific reasoning abilities remain low. According to the 2018 PISA (Programme for International Student Assessment) report, Indonesia ranked 36th in scientific reasoning skills among participating countries (Schleicher, 2019). This suggests that students struggle to apply their scientific knowledge to explain phenomena meaningfully. One contributing factor is that science education in Indonesia tends to emphasize rote memorization rather than inquiry-based learning. Students are rarely trained to construct explanations based on evidence and logical reasoning, leading to weak scientific literacy.

Observations and surveys conducted at SMAN 1 Leces Probolinggo further confirm that students face difficulties in developing scientific explanation skills. 65.6% of students reported challenges in constructing scientific explanations, while 78.1% were unaware of their level of competence in this skill. Additionally, 87.5% of students acknowledged the importance of scientific explanation skills in enhancing their learning experience. Interviews with biology teachers revealed that traditional lecture-based instruction dominated classroom activities, making students passive learners. As a result, students were not effectively engaged in scientific reasoning activities, leading to poor performance in constructing well-supported explanations.

Prior research suggests that effective instructional materials can significantly enhance students' scientific reasoning abilities (Wahyuni et al., 2025; Wulandari et al., 2024). Studies indicate that inquiry-based learning approaches and interactive instructional media can foster better engagement and deeper understanding (Yasmini, 2022; Dalimunthe, 2021). One promising approach is the use of e-booklets, digital booklets that combine text, images, and interactive elements to facilitate self-paced learning (Nasution, 2024). Unlike traditional printed booklets, e-booklets are more accessible, cost-effective, and engaging for students, allowing them to revisit content anytime and anywhere. Studies have shown that the use of digital learning media, such as e-booklets, can improve students' conceptual understanding and motivation, leading to better learning outcomes (Bahrudin & Yogihati, 2022; Byusa et al., 2022; Puspitarini & Hanif, 2019).

Given these findings, this study aims to investigate the effectiveness of an e-booklet in enhancing students' scientific explanation skills in the human immune system topic. The e-booklet was previously validated and tested for practicality, and this research focuses on evaluating its effectiveness. The central research question is How does the e-booklet influence students' scientific explanation skills in the human immune system topic among 11th-grade science students at SMAN 1 Leces Probolinggo during the 2022/2023 academic year?.

METHOD

This study employed a quasi-experimental research design (Sugiyono, 2013) to examine the effectiveness of an e-booklet in enhancing students' scientific explanation skills in the human immune system topic. The research was conducted at SMAN 1 Leces Probolinggo, involving two groups: an experimental class using the e-booklet and a control class following conventional learning methods. The participants included 31 students in class XI IPA 3 as the experimental group and 31 students in class XI IPA 2 as the control group. The purpose of this study was to assess whether the e-booklet could significantly improve students' scientific explanation skills, as determined by a pretest-posttest control group design.

The sample selection was conducted using the Cluster Random Sampling technique. The four XI IPA classes at SMAN 1 Leces Probolinggo were randomly assigned by drawing lots, ensuring an unbiased selection of the experimental and control groups. The implementation phase included the administration of pretests before instruction and posttests after the intervention to evaluate learning gains. The control group engaged in traditional instructional methods, while the experimental group utilized the e-booklet designed for this study.

The data collected in this study consisted of both quantitative and qualitative data. The quantitative data were derived from students' pretest and posttest scores, which were statistically analyzed to determine the effectiveness of the e-booklet. The qualitative data comprised feedback, comments, and suggestions from students and educators regarding the implementation of the e-booklet. These data provided insight into students' experiences and engagement with the learning material.

To measure students' scientific explanation skills, a formative assessment was developed, aligned with three key indicators: claim, evidence, and reasoning (Astutik et al., 2023; Rojikin et al., 2022; Lestari et al., 2021; Kirana et al., 2019). The test consisted of structured questions designed to assess students' ability to construct scientific explanations based on given scenarios. A scoring rubric was utilized to evaluate students' responses, with scores ranging from 0 (no response or incorrect response) to 2 (accurate and well-supported response). The rubric was adapted to assess how well students articulated claims, provided supporting evidence, and justified their reasoning.

The effectiveness of the e-booklet was determined through statistical analysis using a pretest-posttest control group model. Data analysis included prerequisite tests such as normality and homogeneity tests, followed by hypothesis testing using t-tests and the N-gain test. Normality tests were conducted using the Kolmogorov-Smirnov method, given that the sample size exceeded 30 students. This test determined whether the data followed a normal distribution. If the significance value was greater than 0.05, the data were considered normally distributed, allowing for parametric testing. Otherwise, a non-parametric test, such as the Mann-Whitney test, was used.

The homogeneity test was conducted to compare variance across the two groups, ensuring comparability before conducting further analysis. The t-test was employed for parametric data to assess differences in students' pretest and posttest scores. A significance level of less than 0.05 indicated a statistically significant difference between the experimental and control groups. If the data did not meet parametric assumptions, the Mann-Whitney test was applied.

To further evaluate the impact of the e-booklet, the N-gain test was conducted to measure the magnitude of improvement in scientific explanation skills. The N-gain score was calculated using Hake's (1998) formula. The N-gain values were classified into three categories: high ($g \geq 0.7$), moderate ($0.3 \leq g < 0.7$), and low ($g < 0.3$). These categories allowed for an assessment of whether the intervention had a substantial impact on students' learning outcomes.

FINDINGS AND DISCUSSION

The findings revealed a significant improvement in the scientific explanation skills of students in the experimental class who used the e-booklet compared to those in the control class, which relied on conventional learning methods. The pretest results showed that both groups had comparable initial scientific explanation skills, with an average score of 25.45 for the control class and 21.03 for the experimental class. The Mann-Whitney test confirmed no significant difference between the two groups in the pretest phase ($p>0.05$), ensuring that both classes started with a relatively similar baseline knowledge. However, posttest results demonstrated a stark contrast in performance, with the experimental class achieving an average score of 61.5, significantly higher than the control class's 33.45. The Mann-Whitney test for the posttest yielded a p-value < 0.05, indicating a statistically significant difference in favor of the e-booklet intervention.

The normality test results suggested that while the posttest data of the experimental class followed a normal distribution ($p>0.05$), other datasets did not. The homogeneity test further indicated that the data were not homogeneous, necessitating the use of a non-parametric test. The Mann-Whitney test validated the hypothesis that the e-booklet significantly enhanced students' scientific explanation skills.

A more detailed analysis using the N-gain test highlighted the degree of improvement. The control class achieved an N-gain score of 0.142, classified as low, while the experimental class recorded an N-gain of 0.507, falling within the medium effectiveness range. This suggests that the e-booklet effectively facilitated learning and comprehension of scientific concepts. The ability of students in the experimental group to construct scientific explanations improved significantly, particularly in identifying claims, providing supporting evidence, and using reasoning to connect these elements.

Further investigation into the specific indicators of scientific explanation skills: claims, evidence, and reasoning, revealed distinct patterns. The claim component exhibited the highest improvement, with an N-gain of 0.852 in the experimental class, compared to 0.459 in the control class. This suggests that students found it easier to articulate clear claims when supported by structured materials in the e-booklet. Evidence, the second-highest indicator, showed moderate improvement, with the experimental class scoring 0.418 and the control class scoring only 0.025. This disparity indicates that the e-booklet provided structured guidance that helped students better identify relevant supporting data. The reasoning component, however, remained relatively low, with an N-gain of 0.201 in the experimental class and 0 in the control class. This aligns with previous studies indicating that students struggle with connecting claims and evidence logically, a skill that requires higher-order cognitive processing. These findings are visually represented in Figure 1 below.

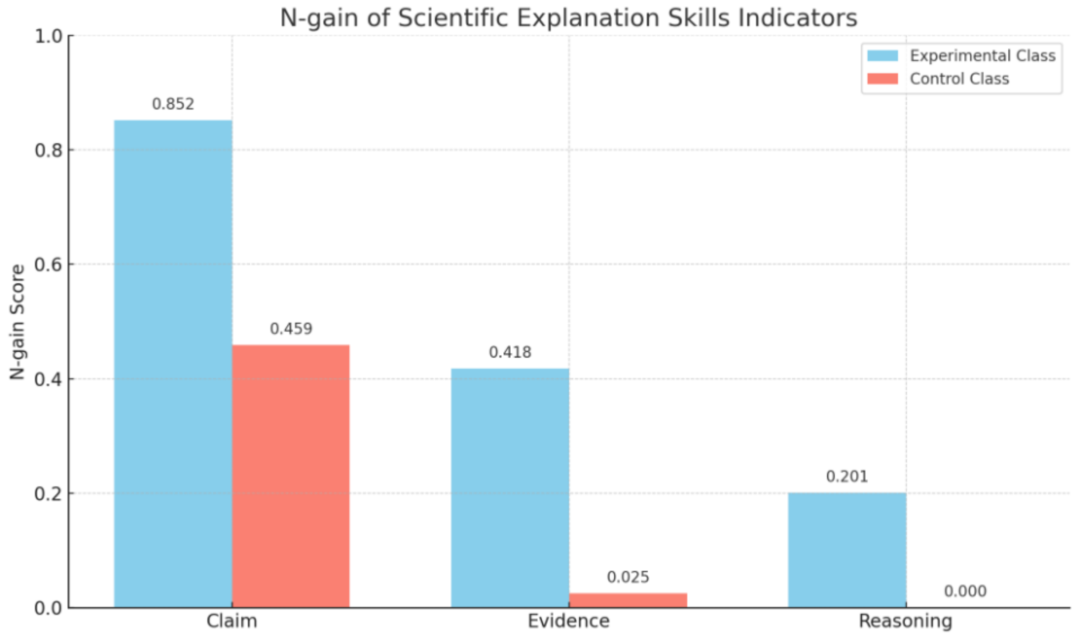

Figure 1. Comparison of N-gain scores for scientific explanation indicators in experimental and control classes.

The positive impact of the e-booklet can be attributed to its ability to present complex biological concepts in a structured, visually engaging, and interactive manner (Mubin et al., 2024; Lestari et al., 2024). Unlike conventional textbooks or teacher-centered explanations, the e-booklet allowed students to learn at their own pace, reinforcing understanding through self-guided exploration (Oktariani, 2024; Tsani & Saptono, 2023). The integration of multimedia elements, such as diagrams and interactive assessments, likely played a crucial role in enhancing retention and comprehension.

Another factor contributing to the effectiveness of the e-booklet was its alignment with active learning principles. By encouraging students to engage with the material actively rather than passively receiving information, the e-booklet facilitated a deeper understanding of the human immune system (Fajarianingtyas et al., 2023). Active learning strategies, such as inquiry-based approaches and guided questioning embedded within the e-booklet, supported students in constructing meaningful explanations. This suggests that incorporating such digital learning tools can bridge the gap between theoretical understanding and practical application.

Despite the overall effectiveness of the e-booklet, the relatively lower improvement in reasoning skills suggests the need for further instructional support. Future iterations of the e-booklet could incorporate scaffolded reasoning exercises, where students practice linking claims and evidence systematically.

Given these findings, further research is recommended to explore the long-term impact of e-booklets on student learning. Future studies could investigate how sustained use of digital resources influences retention rates and overall academic performance. Additionally, qualitative research focusing on student experiences and perceptions could provide deeper insights into how digital tools shape learning behaviors.

CONCLUSION

The findings of this study confirm that the implementation of an e-booklet significantly improves students' scientific explanation skills in the human immune system topic. The experimental class demonstrated a higher learning gain compared to the control class, as evidenced by the N-gain analysis and statistical significance in posttest scores. The e-booklet proved effective in strengthening students' ability to construct scientific claims and provide supporting evidence, although reasoning skills require further instructional support.

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