

## THE EFFECTIVENESS OF A STEM-BASED SCIENCE COMIC E-WORKSHEET ON ECOLOGY MATERIALS FOR ENHANCING STUDENTS' PROBLEM-SOLVING SKILLS

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### ABSTRACT

Problem-solving skills are among the essential competencies required for 21st-century science education; however, students' proficiency in these skills remains relatively low, particularly in ecology learning. This study aimed to analyze the effectiveness of a STEM-based science comic e-worksheet in enhancing students' problem-solving skills. The study employed a pre-experimental one-group pretest-posttest design involving 31 seventh-grade students at a public junior high school in Semarang, Indonesia. The Polya-based problem-solving test was validated by five experts, yielding validity coefficients of 0.87–0.93. Data were analyzed using a normality test, paired-sample t-test, and normalized gain (N-Gain) test. The mean pretest score increased from 46.27 to 77.79 on the posttest. The average N-Gain score was 0.6025, indicating moderate improvement, with the highest gains in understanding the problem (0.8367) and looking back (0.7161). The results demonstrate that the STEM-based science comic e-worksheet effectively enhances students' problem-solving skills in ecology.

**Keywords:** e-worksheet; science comic; STEM; problem-solving skills; ecology

### INTRODUCTION

Contemporary educational developments necessitate that students acquire essential competencies to adapt effectively to the rapid advancement of science and technology (Klaharn et al., 2025; Suharyat et al., 2023). One of the essential competencies that students need to develop in this era of global advancement is problem-solving skills (Topsakal et al., 2022). Effective problem-solving requires integrating multiple concepts, reflecting the need for higher-order thinking skills to apply knowledge in meaningful contexts (Anggrainly & Ananda, 2025). These skills serve as a bridge between academic knowledge and real-world problems encountered in everyday life (Kaya-Capocci et al., 2025). Therefore, problem-solving skills are essential for enabling

students to identify problems and develop effective solutions in response to increasingly complex global challenges (Daniel et al., 2025; Widodo et al., 2023).

Problem-solving skills encompass cognitive processes that involve understanding the problem, devising a plan, carrying out the plan, and looking back to assess the effectiveness of the solution (Polya, 1945; Yapatang & Polyiem, 2022). The development of these skills can be facilitated by presenting contextual problems, which play a crucial role in science learning (Anas et al., 2025; Gcabashe, 2024; Gülay et al., 2023). Nevertheless, students' achievement in problem-solving skills in Indonesia remains relatively low. The 2022 PISA results indicate that only 34% of Indonesian students achieved the minimum level of

science proficiency, with the national average remaining below the international average, particularly on science tasks requiring problem-solving skills (OECD, 2023).

The low level of problem-solving skills among secondary school students can be attributed to the limited availability of instructional materials during the learning process. Ideally, student worksheets should function as strategic instructional tools that guide students through systematic problem-solving processes (Manggarrani & Marhaeni, 2025). However, in practice, most worksheets currently used in schools remain highly procedural and conventional, consisting primarily of content summaries and routine practice questions. This issue is further corroborated by Utari et al. (2025) who found that commonly used worksheets are not designed based on specific learning model syntax and remain overly simplistic in both content and design. A rigid approach to presenting learning materials limits opportunities for students to engage in exploration, inquiry, and deeper reasoning, which are essential for developing problem-solving skills (Fina et al., 2023; N. Sari et al., 2025).

This condition was also identified in a preliminary study conducted in Class VII G at SMP Negeri 39 Semarang. The initial assessment revealed that students' problem-solving skills had not yet reached optimal levels. The preliminary data showed that 64.52% of students scored below the minimum proficiency criterion. Most of these students experienced difficulties in planning problem-solving strategies, implementing appropriate solutions, and evaluating the outcomes of their problem-solving processes. These findings indicate the urgent need for innovative instructional materials that can be empirically validated

to support students in developing problem-solving skills across each stage of the process. As Agustin et al. (2025) emphasize, the use of interactive media serves as an innovative alternative to address current educational challenges, particularly in supporting the improvement of student learning outcomes on ecology topics.

Electronic worksheets have emerged as an innovative instructional alternative that leverages technological advances to enhance the quality of learning. E-worksheets facilitate a more interactive, visual, and flexible presentation of learning materials, thereby enhancing students' problem-solving skills while supporting both independent and guided exploration of concepts (Mayasari et al., 2023; Ramadhan & Sumarni, 2025; Wijaya & Wilujeng, 2024). As highlighted by Aulya et al. (2025), the application of appropriate learning media can foster student activeness and increase their engagement in learning activities, thereby leading to better conceptual understanding. The effectiveness of e-worksheets can be further enhanced by presenting learning materials as science comics (Fajar et al., 2022; Putra et al., 2023; D. A. Sari & Zakariyah, 2023). Science comics effectively combine visual illustrations with scientific narratives, helping students understand abstract concepts and identify problems through contextual storylines (Ayu et al., 2025; Rani & Asdarina, 2024).

The learning approach, along with instructional media, is essential for developing students' problem-solving skills. The STEM approach brings together diverse fields, encouraging creative problem-solving through hands-on analysis, inventive design, and the development of practical solutions for real-

world challenges (Khurma & Darayseh, 2023; Sheth & Pathak, 2023). Furthermore, the STEM approach encourages students to participate in project- and inquiry-based learning activities, thereby fostering higher-order thinking skills, including problem-solving (Novitasari et al., 2024; Ortiz-Revilla et al., 2022).

This study integrates the STEM approach into a STEM-based science comic e-worksheet on ecology materials as an instructional innovation. Conventional e-worksheets generally provide only digital learning content accompanied by practice exercises, whereas the developed e-worksheet presents contextual ecological problems through science comic narratives. Students are guided to solve these problems systematically by integrating concepts from science, technology, engineering, and mathematics. This structured problem-solving process encourages students not only to acquire conceptual knowledge but also to develop critical thinking skills. The strengths of this instructional material lie in its engaging visual presentation and its ability to foster students' independence in solving problems. This aligns with the characteristics of effective digital media, such as Hyzine-flipbook assisted modules, which offer interactive content, easy accessibility, and visually appealing designs that support independent learning (Haiban & Arini, 2025).

Despite these potential benefits, quantitative studies specifically investigating the effectiveness of STEM-based science comic e-worksheets on ecology materials at the junior high school level remain scarce. Most existing research has either examined e-worksheets and science comics separately or focused on different subject matters, without integrating the STEM approach into a

comic-based digital worksheet for ecology. Furthermore, few studies have employed experimental designs to provide empirical evidence of the impact of such integrated media on students' problem-solving skills. This gap highlights the need for systematic investigation to validate the instructional effectiveness of this innovation.

This study examines the effectiveness of a STEM-based science comic e-worksheet on ecology materials in improving students' problem-solving skills. This study aims to provide empirical evidence on the effectiveness of this instructional material as an innovative approach to developing students' problem-solving skills in ecology.

## **METHOD**

This study used a quantitative, pre-experimental one-group pretest-posttest design (Creswell & Creswell, 2018). The effectiveness of the intervention was evaluated by comparing students' problem-solving skill scores before and after implementing learning using the STEM-based science comic e-worksheet on ecology materials. The study was conducted at SMP Negeri 39 Semarang from March to April 2026.

The study population included all seventh-grade students at SMP Negeri 39 Semarang, across multiple parallel classes. Class VII G (n=31) was selected through purposive sampling based on criteria of low pretest scores, schedule feasibility, and adequate digital literacy. While purposive sampling is appropriate for this pre-experimental design, it introduces selection bias and limits generalizability; accordingly, this study focuses on preliminary effectiveness rather than broad causal inferences, and future research

should consider random sampling to enhance external validity.

Data were analyzed using the N-Gain test to assess intervention effectiveness. A normality test was performed before hypothesis testing to assess whether the data met the assumption of normality. A paired-sample t-test was conducted at  $\alpha = 0.05$  to assess whether a statistically significant difference existed between students' pretest and posttest scores.

## RESULT AND DISCUSSION

The effectiveness of the STEM-based science comic e-worksheet on students' problem-solving skills in ecology was assessed by comparing pretest and posttest scores following the learning intervention. The effectiveness analysis consisted of descriptive statistics, prerequisite testing, hypothesis testing, and N-Gain analysis. Enhancements in students' problem-solving abilities were evaluated using Polya's four-stage framework: understanding the problem, devising a plan, carrying out the plan, and looking back (Polya, 1945; Yapatang & Polyiem, 2022). An indicator-based analysis was conducted to provide a comprehensive understanding of students' progress at each stage of the problem-solving process. This approach is consistent with Siswanto (2025), who emphasized that e-worksheets facilitate students' systematic engagement in problem-solving, from understanding the problem to evaluating the proposed solution.

The test instrument was assessed for validity by five experts before being used to measure students' problem-solving skills. It comprised 13 items representing Polya's four problem-solving indicators: understanding the problem, devising a plan, carrying out the plan, and looking back. Validity analysis showed that all items met

the criteria, with coefficients ranging from 0.87 to 0.93, indicating that each item validly measured the intended aspects. Consequently, all 13 items were retained for the pretest and posttest.

Table 1. Descriptive Statistics of Students' Problem-Solving Skills

| Variable | N  | Mean  | Std.  |
|----------|----|-------|-------|
| Pretest  | 31 | 46,27 | 9,05  |
| Posttest | 31 | 77,79 | 11,40 |

Based on Table 1, the mean score for students' problem-solving skills increased from 46.27 on the pretest to 77.79 on the posttest, representing an improvement of 31.52 points. This finding indicates a substantial enhancement in students' problem-solving performance following the implementation of the STEM-based science comic e-worksheet on ecology materials. The improvement suggests that students became better able to understand and solve ecology-related problems after participating in learning activities supported by the e-worksheet. This finding is consistent with Risamasu & Pieter (2024), who reported that e-worksheets presenting contextual problems encourage students to analyze problems systematically and develop solutions based on the knowledge acquired during the learning process. Similarly, Subekti & Andriyani (2023), found that the implementation of electronic worksheets effectively improves higher-order thinking skills, including problem-solving skills. Nevertheless, before conducting hypothesis testing, a normality test was performed to ensure that the observed improvement was statistically significant and not due to chance.

Table 2. Results of the Normality Test for Pretest and Posttest Data

| Data     | Sig.  | Description |
|----------|-------|-------------|
| Pretest  | 0,159 | Normal      |
| Posttest | 0,523 | Normal      |

The normality test results show that the pretest and posttest data had significance values greater than 0.05, indicating that both datasets are normally distributed. The assumption of normality was satisfied. A paired-samples t-test was subsequently performed to assess whether the difference between students' pretest and posttest scores was statistically significant.

Table 3. Results of the *Paired-Sample t-test*

| t       | df | Sig. (2-tailed) |
|---------|----|-----------------|
| -21,673 | 30 | 0,000           |

Table 3 indicates that the paired-sample t-test produced a significance value ( $p$ ) of 0.000, which is below the established significance threshold of 0.05. A  $p$ -value below the established significance level leads to rejection of the null hypothesis, indicating a statistically significant difference between pretest and posttest scores (Kwak, 2023). The results indicate that implementing the STEM-based science comic e-worksheet for ecology materials effectively enhanced students' problem-solving skills. This conclusion is corroborated by the N-Gain analysis, which quantifies the degree of student improvement following the instructional intervention.

Table 4. N-Gain Analysis Results

| Average N-Gain | Category |
|----------------|----------|
| 0,6025         | Moderate |

The average N-Gain score of 0.6025 falls within the moderate category based on

the normalized gain criteria (Dalila et al., 2022). The STEM-based science comic e-worksheet on ecology significantly improved students' problem-solving skills. This result aligns with Mayasari et al. (2023) and Wijaya & Wilujeng (2024) who found that e-worksheets increase learning engagement and support higher-order thinking through interactive activities.

The observed improvement can be attributed to the features of the developed e-worksheet, which presents learning materials digitally and incorporates science comics as a contextual learning medium. Through contextual storylines, science comics help students understand abstract concepts and identify problems encountered in real-life situations (Ayu et al., 2025; Rani & Asdarina, 2024). Furthermore, the STEM approach, implemented through project-based learning activities, encourages students to integrate concepts from science, technology, engineering, and mathematics as they analyze and solve problems. This interdisciplinary learning process enables students to develop more systematic and effective problem-solving skills (Khurma & Darayseh, 2023; Novitasari et al., 2024).

These findings were further analyzed by indicators of problem-solving skills to identify which aspects showed the greatest improvement following the implementation of the STEM-based science comic e-worksheet on ecology materials.

Table 5. N-Gain Scores Based on Problem-Solving Skills Indicators

| Indicator                 | N-Gain | Category |
|---------------------------|--------|----------|
| Understanding the problem | 0,8367 | High     |
| Devising a plan           | 0,4775 | Moderate |
| Carrying out the plan     | 0,5841 | Moderate |
| Looking back              | 0,7161 | High     |

Based on Table 5, all indicators of students' problem-solving skills showed improvement following the implementation of the STEM-based science comic e-worksheet on ecology materials. The indicator for understanding the problem showed the greatest improvement, as evidenced by an N-Gain score of 0.8367. This result indicates that presenting ecological phenomena through science comics effectively helps students identify essential information, understand the relationships among ecosystem components, and determine the core of a problem before formulating an appropriate solution. This finding is consistent with Ayu et al. (2025), which states that comics can visualize abstract scientific concepts through stories and illustrations, making them easier for students to understand more concretely.

This quantitative finding was reinforced by student reflections and the researcher's observation notes. One student stated, *"The comic made the concept of ecosystem balance easier to grasp because I could see the cause-and-effect relationships in the pictures."* During the initial lesson, the researcher also observed that students identified key information from the comic narratives more quickly than in conventional lessons and asked fewer clarifying questions.

Science comics offer contextual learning experiences that align with students' everyday lives, facilitating connections between ecological concepts and real-world environmental phenomena. This supports the view of Yapatang & Polyiem (2022), who argued that understanding the problem is the fundamental stage of problem-solving because students must first identify the available information, determine the

information required, and clearly define the problem before developing an appropriate solution strategy.

The devising a plan indicator obtained an N-Gain score of 0.4775, representing the lowest improvement among all problem-solving indicators. This finding suggests that students' ability to design appropriate solution strategies still requires more intensive practice. At this stage, students are expected to identify alternative solutions, evaluate possibilities, and integrate STEM concepts into their proposed solutions. This finding is consistent with the Yapatang & Polyiem (2022) study, which explains that the planning stage involves selecting the most appropriate strategy based on the information obtained during the previous stage.

Qualitative data further elucidated the moderate improvement in this indicator. Several students wrote, *"We knew what the problem was, but deciding which STEM steps to take first was the hardest part."* The researcher's field notes corroborated this challenge, documenting that groups often deliberated extensively on selecting appropriate technological tools and mathematical formulas, which frequently required the researcher to provide structured scaffolding to guide their planning.

The STEM approach requires students to integrate multiple disciplines through engineering design activities to develop solutions to authentic problems, thereby demanding more advanced analytical and decision-making skills (Khurma & Darayseh, 2023; Ortiz-Revilla et al., 2022). Although the improvement was categorized as moderate, the findings indicate that the STEM-based project activities incorporated into the e-worksheet

have provided valuable learning experiences that support students in developing systematic solution-planning skills, while highlighting the need for continued practice through sustained learning experiences.

The carrying out the plan indicator achieved an N-Gain score of 0.5841, classified as moderate. The looking-back indicator recorded an N-Gain score of 0.7161, indicating a high level of improvement. This finding is particularly striking, as previous research has identified the looking back indicators as the most challenging aspect of problem-solving for Indonesian students (Apriyanti et al., 2026). The fact that the present intervention achieved the highest improvement in this traditionally weakest area suggests that the STEM-based science comic e-worksheet effectively addresses this chronic weakness. The improvement observed in both indicators suggests that students became increasingly capable of implementing the solutions they had designed and evaluating their effectiveness.

According to Yapatang & Polyiem (2022), the carrying out the plan stage emphasizes implementing the selected solution strategies, whereas the looking back stage focuses on evaluating both the problem-solving process and its outcomes to ensure that the proposed solutions are appropriate. The project activities, group discussions, presentations, and reflection sessions integrated into the e-worksheet provided students with meaningful opportunities to apply ecological concepts to authentic environmental problems and evaluate the solutions they developed. These findings are consistent with the characteristics of STEM learning, which emphasizes designing, testing, and refining solutions through engineering design

activities (Khurma & Darayseh, 2023; Ortiz-Revilla et al., 2022).

The improvements in execution and evaluation stages were also evident in the researcher's observation records. During project-making sessions, the researcher noted that students demonstrated growing persistence in testing and revising their proposed solutions. A student reflection captured this process: *"When our first design failed, we discussed why and tried a different approach—it felt like real scientists."* Another student remarked, *"The reflection session made me realize that our solution wasn't perfect, but we learned how to improve it."* These qualitative insights validate that the group discussions and reflection activities embedded in the e-worksheet effectively fostered metacognitive awareness, supporting the high N-Gain observed for the looking-back indicator.

Reflection activities prompt students to re-examine their reasoning processes and evaluate their problem-solving outcomes. This practice supports the development of the metacognitive skills necessary to assess the effectiveness of generated solutions (Rivas et al., 2022; Winarti et al., 2022). Integrating science comics with the STEM approach enhances students' conceptual understanding of ecology and supports the development of problem-solving skills at each stage outlined in Polya's framework.

## CONCLUSION

This study demonstrates that the STEM-based science comic e-worksheet on ecology materials is effective in enhancing students' problem-solving skills. Analysis based on Polya's four stages revealed that the greatest improvements were achieved in the understanding the problem and looking back stages. The results provide empirical

evidence that integrating science comics with the STEM approach in e-worksheets enhances students' conceptual understanding of ecology and supports the development of problem-solving skills at each stage, as outlined in Polya's problem-solving framework. However, these findings should be interpreted with caution regarding generalizability, as they are limited to the specific educational context of a single seventh-grade classroom at SMP Negeri 39 Semarang, the ecology materials employed, and the two-month intervention period. Therefore, the developed e-worksheet has the potential to serve as an innovative instructional resource for science education and may be adapted for other science topics to foster students' problem-solving skills. Future studies are recommended to examine its applicability across diverse educational contexts, grade levels, subject topics, and extended timeframes to validate broader implementation. Furthermore, the findings contribute to the growing body of evidence supporting the integration of STEM and science comics into digital instructional materials as an effective strategy for enhancing students' problem-solving skills in science education.

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