The Effectiveness of E-Comic Media Based on Scientific Literacy for Teaching Single and Mixed Substance Materials

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Article Info

Abstract

This study aims to assess the effectiveness of scientific literacy-based e-comic media in improving students' learning outcomes related to the topic of single substances and mixtures. A quasi-experimental design with a pretest-posttest approach was employed, where the same group of 25 students from class VA at SDN Sampangan 02 and class VB at SD Lab School UNNES were tested before and after using the e-comic media. The e-comic was designed to engage students and enhance their understanding of scientific concepts through interactive narratives and visual illustrations. The study found that the use of e-comic media significantly improved students' learning outcomes, as indicated by the results of a paired t-test ($t = 9.766$, $p < 0.05$) and N-gain analysis, which showed a medium level of improvement (N-gain = 0.584). Teacher and student responses were overwhelmingly positive, with 93% and 95% satisfaction rates, respectively. This suggests that e-comic media is an effective tool for improving students' scientific literacy and understanding of the material. The findings support the use of digital media in science education, particularly for engaging students in complex scientific concepts.

How to Cite

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INTRODUCTION

Natural Sciences is one of the mandatory subject contents in the 2013 curriculum structure at the elementary school education level, which plays an important role in the survival of humans and the universe. According to Yuliati and Lestari (2020), science education provides a framework for developing cognitive and practical skills that enable students to explore and interact with their environment through inquiry-based learning. By studying science, students not only acquire knowledge but also develop critical thinking skills to understand complex phenomena and solve problems in their daily lives.

An essential aspect of learning science is scientific literacy, which is closely linked to students' ability to understand and apply scientific concepts. The Program for International Student Assessment (PISA, 2019) defines scientific literacy as the ability to engage with science-related issues, apply scientific knowledge, evaluate evidence, and make informed decisions about the natural world and human activities. This framework highlights the significance of contextualizing science learning in real-life applications, fostering critical thinking, and promoting active problem-solving skills (OECD, 2019). Therefore, fostering scientific literacy from an early age is crucial, as it forms a foundational skill that students must develop (Yuliati, 2017:21). The government supports this through the implementation of the 2013 curriculum, aiming to ensure that students acquire strong scientific literacy skills. In fact, in international relations, scientific literacy is one of the three key parameters used to measure a nation's progress (Rubini et al., 2017:9).

However, based on identification activities problems carried out by researchers in the VB SD Lab School UNNES class, researchers found several obstacles in science learning due to the lack of digital-based learning media that could explore students' scientific literacy abilities. VB SD Lab School UNNES is a laboratory primary school affiliated with Universitas Negeri Semarang (UNNES), located in Semarang, Indonesia. This school serves as a model institution for educational research and development, implementing the 2013 curriculum with a focus on active and inquiry-based learning. The VB class consists of 16 students, representing a typical small-sized classroom setting in Indonesia. This problem is supported by science learning results document data which shows that there are still scores below the minimum completeness criteria. The results of student achievement were 10 out of 16 students or 62% had reached the KKM. Meanwhile, the remaining 6 students have not reached the KKM or 38%.

To overcome this problem, researchers provide a solution to develop innovative learning media based on scientific literacy, namely e-comic media or electronic comics. E-comic media is a digital educational tool that integrates graphic illustrations and interactive narratives into a cohesive digital format, making it both engaging and effective for learning. According to Widyastuti and Suryani (2020), e-comics combine storytelling and visual elements to convey complex information in a simplified and enjoyable way, which enhances comprehension and retention. This digital medium has proven to be a versatile tool in education, capable of increasing students' motivation, creativity, and engagement with the material (Prasetyo & Wahyudi, 2021).The use of e-comic media is supported by Sudjana and Rivai (2019:68) who argue that through the use of comic books as learning media by educators the benefits obtained are that they can increase knowledge of previously unknown vocabulary, improve reading skills, arouse interest in learning, and to expand the literacy movement.

The development of E-Comic media based on scientific literacy refers to previous research. Research by Roswati et al. (2019), titled "The Development of Science Comic in Human Digestive System Topic for Junior High School Students," aimed to develop and evaluate science comics for teaching the Human Digestive System Topic (HDST). The results showed that most students agreed that science comics helped simplify science concepts and make topics more accessible. Similarly, students' scientific literacy competencies have been shown to impact learning outcomes. This is evident from Avikasari et al. (2018) in their study titled "The Influence of Science Literacy-Based Teaching Material towards Science Achievement," which examined the effect of science literacy-based materials on fourth-grade students' science achievements. Their findings indicated a significant improvement in test scores after the implementation of these materials.

However, the novelty of this research lies in the evaluation of the effectiveness of e-comic media specifically designed to improve elementary school students' understanding of single and mixed substances. Unlike previous studies, which focused on other scientific topics or general learning materials, this research targets the integration of scientific literacy into digital comic media tailored for the specific topic of single and

mixed substances, a core concept in elementary science education. This media not only simplifies complex scientific concepts but also incorporates interactive features such as quizzes and games, making it more engaging and potentially effective in enhancing both students' scientific literacy and their overall learning outcomes.

The primary focus of this research is to evaluate the effectiveness of e-comic learning media, based on scientific literacy, in improving student learning outcomes related to the topic of single and mixed substances. This study employs a quasi-experimental design with a pretest-posttest approach to measure changes in students' knowledge and understanding before and after using the e-comic media. Therefore, this research aims to analyze the effectiveness of E-Comic learning media based on scientific literacy on single and mixed substance material to improve student learning outcomes for science lesson content in class VB SD Lab School UNNES.

METHOD

This study employs a quasi-experimental design using a pretest-posttest approach to assess the effectiveness of e-comic media in improving students' learning outcomes related to the topic of single substances and mixtures. The study aims to determine whether the use of e-comic media significantly enhances students' understanding of scientific concepts.

The research subjects consisted of 25 students from two classes: VA at SDN Sampangan 02 and VB at SD Lab School UNNES. The same group of students was tested both before and after using the e-comic media, with the pretest assessing students' baseline knowledge and the posttest measuring their learning outcomes after interacting with the e-comic.

In this quasi-experimental design, no control group was used. The focus is on observing the changes within the same group of students after the intervention (e-comic media). The independent variable in this study is the e-comic media based on scientific literacy, while the dependent variable is the students' learning outcomes, specifically related to the topic of single substances and mixtures.

To analyze the data, quantitative methods were employed. A paired t-test was conducted to compare the pretest and posttest scores and determine whether there was a significant improvement in students' learning outcomes after using the e-comic. The significance level was set at $p<0.05$. Additionally, N-gain

analysis was performed to measure the degree of improvement, categorizing the results into low, medium, or high improvement levels. This analysis allows for a more nuanced understanding of the effect of the e-comic on students' learning.

Furthermore, a reliability test was conducted on the instruments used for data collection (e.g., pretest, posttest, and questionnaires) to ensure consistency in the measurements, with a Cronbach's Alpha coefficient of $\alpha \geq 0.7$ considered acceptable.

This approach allows for an in-depth evaluation of the effectiveness of the e-comic media in enhancing students' understanding of science concepts, particularly single substances and mixtures, and provides insights into how interactive digital media can improve learning outcomes.

RESULT AND DISCUSSION

E-Comic media based on scientific literacy is a digital comic in the form of an interactive power point and Android application so that it can be operated via PC/laptop and smartphone. At this stage the researcher used several applications for creating comics, creating media, publishing links and converting PowerPoint into an Android application. The application for creating illustrations used by researchers is the Android application "color" which can be downloaded via Playstore. The size of each panel varies from 1:1 and 16:9 to create the impression of closure as a characteristic of comics. The brush used is an artistic brush with a size of 20px, while the font on the text balloon uses the schoolbell font. The illustrations created adapt the media prototype design with the characters Nino and the magic glass as the main characters accompanied by the characters of the teapot mother and the bottle father. There are 2 settings in the story, namely Nino's room and the kitchen.

After creating the comic illustrations, the researcher created the core media using the Microsoft PowerPoint application on a laptop with a widescreen slide size of 16:9. Previously, researchers had prepared backgrounds and supporting images as menu icons to support media visualization. To create a science e-comic logo, researchers also used the Corel Draw X7 application with book details containing science icons. Researchers arrange the media according to the prototype design starting from the front page or cover then the application menu which contains foreword symbols, KI/KD, indicators, learning objectives, instructions for use, e-comics, quizzes and LKPD, summaries, practice questions, ga-

mes, biodata and bibliography hyperlinked to the slides according to the title. Researchers predominantly use comic sans and constantia fonts as well as cooper black.

In the next stage interactive powerpoint which has been completed is then published using the ispring9 application which has been integrated with Powerpoint to become an HTML link in the folder. The HTML link is converted into an Android application using the WEB2APK application. This convert application can only be downloaded via PC/laptop. The researcher enters the name of the application, selects the rotation orientation, selects the publish file folder and the application icon image according to the column provided. Researchers can also set the required full screen, zoom button and toolbar settings. Next, the researcher pressed the GENERATE APK button to start converting the HTML file into an Android application file. The result of the conversion process is an apk file that can be sent to teachers and students via Whatsapp or other file sending media.

The e-comic developed in this study integrates scientific literacy indicators to enhance students' understanding of single substances and mixtures. Each section of the e-comic is designed to address one or more of the key aspects of scientific literacy as defined by the OECD (2019): content, process, context, and attitudes. Below is a detailed explanation of how each part of the e-comic incorporates these scientific literacy indicators:

Figure 1. Science Literacy-Based E-Comic Cover Development Design

The e-comic begins with an eye-catching cover page that introduces the central characters and the main theme of the story. The introduction provides a brief overview of the topic, which is single substances and mixtures, linking it to real-life examples. This section aligns with the content indicator of scientific literacy by presenting key scientific concepts in an engaging, easy-to-understand manner.

Figure 2. Science Literacy-Based E-Comic Menu Application Design

After the front page, the application menu is designed with a user-friendly interface, allowing students to navigate through different sections such as the main comic, quizzes, worksheets (LKPD), and games. The simple and intuitive layout helps students independently access each feature without needing continuous guidance from the teacher.
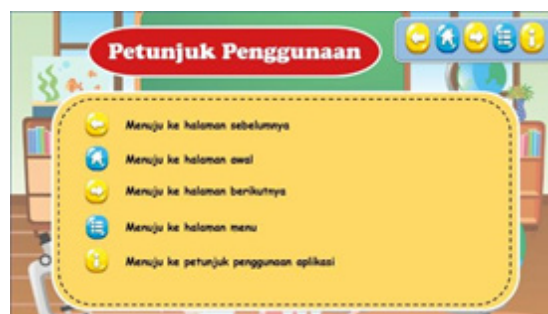

Figure 3. Science Literacy-Based E-Comic User-Guide Design

The user guide provides clear instructions on how to navigate and use the e-comic, both on Android devices and PCs/laptops via PowerPoint. This section includes illustrated step-by-step instructions, ensuring that both students and teachers can maximize the use of the e-comic's features. This supports independent learning, especially in remote learning environments.

Figure 4. Science Literacy-Based E-Comic "Nino & Gelas Ajaib" Design

Figure 5. Science Literacy-Based E-Comic Dialogue Design

The heart of the e-comic is its storyline, which uses visual illustrations to depict scientific concepts. For instance, the characters in the story, Nino and his magical glass, explore various materials and substances. The illustrations visually represent single substances and mixtures, such as salt and sugar (single substances) versus solutions or suspensions (mixtures). This section addresses the content component by explaining scientific concepts through visuals, helping students understand abstract topics. Additionally, it supports the process component by encouraging students to think critically about the properties of the substances depicted.

Figure 6. Science Literacy-Based E-Comic Quiz Design

Figure 7. Science Literacy-Based E-Comic Worksheet Design

After certain sections of the storyline, interactive quizzes are introduced to test students'

understanding of the material (see Figure 6). For example, students are asked to identify whether a substance is a single substance or a mixture based on the story's content. This section fosters the process aspect of scientific literacy by promoting critical thinking and problem-solving. It also encourages students to apply their scientific knowledge to new situations, reinforcing their ability to evaluate evidence and make informed decisions.

To deepen understanding, the e-comic includes worksheets (LKPD) designed to encourage hands-on activities. The e-comic includes scenarios where students are asked to apply what they've learned to real-life contexts. In this section, students are prompted to conduct simple experiments or complete exercises related to the material covered in the comic (see Figure 7). For instance, the characters perform simple experiments, like mixing different substances, to demonstrate how mixtures are formed. These experiments are designed to connect the context component of scientific literacy, making learning more relevant by linking it to everyday experiences. By asking students to consider how the scientific concepts apply to their surroundings, the e-comic enhances students' ability to make connections between theory and practice. The worksheets foster active engagement and improve students' scientific thinking and analytical skills.

Figure 8. Science Literacy-Based E-Comic Guess Game Design

Picture 9. Science Literacy-Based E-Comic Searchword Game Design

The e-comic also offers an interactive game, designed to make learning more enjoyable and engaging. For instance, students are challenged to "guess" whether a substance is a single or mixed substance based on clues provided. This gamified approach not only captures students' attention but also enhances their motivation to learn. Throughout the e-comic, students are encouraged to engage with the content in an interactive and enjoyable way. The use of games, puzzles, and a fun narrative fosters a positive attitude toward science. This section aligns with the attitudes component of scientific literacy by promoting curiosity, interest, and a willingness to learn about scientific topics. The playful nature of the e-comic helps students approach science with a sense of excitement and motivation.

Picture 10. Science Literacy-Based E-Comic Summary Design

At the end of the e-comic, a summary of the material is presented in a visually appealing format, highlighting key points for easy recall, recaps the main concepts covered in the story, providing a concise review of single substances and mixtures. This section helps students revisit the main concepts they have learned throughout the comic, making it a useful tool for review before assessments. This summary section helps reinforce the content indicator by providing a clear and structured recap of the key scientific concepts, allowing students to revisit the material and consolidate their understanding.

The e-comic media developed in this study was designed not only to integrate various aspects of scientific literacy but also to evaluate its effectiveness in improving students' learning outcomes. The initial sections of the e-comic include a cover page, preface, core competencies (KI/KD), indicators, learning objectives, and usage instructions. These components were carefully aligned with the curriculum and aimed to facilitate the understanding of key scientific concepts. Specifically, the learning objectives focused on KD 3.9, which involves classifying materials in daily life based on their components (single substances and mixtures), and KD 4.9, which includes reporting the results of observations on the properties of mixtures and their components.

In this study, the e-comic was used as the primary instructional tool, and its effectiveness was assessed by measuring students' learning outcomes before and after using the media. The pretest-posttest design was employed to evaluate whether students' understanding of the material, particularly regarding single substances and mixtures, significantly improved after interacting with the e-comic. This research aimed to determine if the e-comic media not only facilitated learning but also effectively enhanced scientific literacy and students' ability to apply scientific concepts in real-life situations.

In the core section of the media, the following scientific literacy aspects, as defined by OECD (2019), are implicitly developed: content, process, context, and attitude:

1. Content: This aspect is presented through the storyline and illustrations in the e-comic, which visually represent the concepts of single substances and mixtures.
2. Process: The process aspect is conveyed through the first and second quizzes on elements and compounds, which provide students with opportunities to analyze and identify questions based on prior knowledge.
3. Context: The context aspect is integrated through the LKPD (student worksheet), which encourages students to conduct simple experiments on homogeneous and heterogeneous mixtures.
4. Attitude: The attitude aspect is observed in how students engage in the learning process. However, this aspect was not a focus of assessment in this study.

The final section of the media includes a summary, practice questions for pretests and posttests, a bibliography, and developer information. The visualization and content of the media are designed to be as engaging as possible, in line with the cognitive and emotional levels of the students. The background theme takes inspiration from a school laboratory setting to boost enthusiasm for learning science, specifically the topic of single substances and mixtures. Bright colors are used in the background to create a sharp contrast with the text and illustrations, ensuring that the media is easily readable by both students and teachers.

In addition to aptitude assessment, researchers also perform effectiveness assessments to find out if there is an influence or improve-

ment in student learning outcomes on a subject. The study results referred to in this study are the results of pre-test and posttest material of single substances and mixtures. Students obtain the pretext from the learning outcome before using science literacy based e-comic media, while students obtain posttest results from learning outcomes after using scientific literacy-based e- Comic media. After obtaining both of these learning results, researchers process the data of pretest and posttest using the t and N-gain tests as the final data analysis to determine the effectiveness of science literature based E-comics media.

Table 4. Results of T-Test for Students' Pretest and Posttest

Action	N	Average	t_{value}	t_{table}	Description
Pretest	16	60.06	9.767	2.045	Ho rejected
Postest	16	83.38			Ha accepted

Based on the t test results in table 4, it is known that the calculated t is greater than the t table (9.766539867> 2.045). So Ho is rejected and Ha is accepted, therefore the t test results show that there is a significant influence using e-comic media based on scientific literacy in single and mixed substance material on student learning outcomes.

The data used to analyze the N-gain test descriptively in percentages is data from the pretest and posttest results of the VB SD Lab School UNNES class. The following are the results of the N-Gain calculation on the pretest and posttest results using Microsoft Excel (see Table 5).

Table 5. The N-gain Value of Pretest and Posttest

Action	N	Average	Difference mean score	N-Gain Score	Criteria
Pretest	16	60.06	23.31	0.584	Moderate
Postest	16	83.38			

Based on table 5. N-gain test results, it is known that the difference between the average value of the pretest and posttest values is 23.31 and the N- gain value is 0.584 which means entering the medium criterion. So the conclusion is there is an improvement between the learning results of the pre-test and the posttest with medium criteria.

This study focused on evaluating the effectiveness of e-comic media based on scientific literacy in improving students' learning outcomes, specifically in understanding the topic of single and mixed substances. Unlike previous research which centered on the development of e-comics, this study shifted its focus to empirically testing the effectiveness of the media through an experimental design, using a pretest-posttest approach. This design is well-suited for measuring changes in students' knowledge and skills after the intervention, making it possible to assess whether the e-comic effectively enhanced their scientific literacy.

The results from the t-test (t = 9.766, p < 0.05) demonstrated that the use of e-comic media led to a significant improvement in students' learning outcomes. This significant difference between pretest and posttest scores confirms that the e-comic media had a positive effect on students' understanding of scientific concepts related to single and mixed substances. The N-gain score of 0.584, categorized as medium improvement, further supports the effectiveness of the e-comic in enhancing student learning.

These findings are consistent with previous studies that have examined the use of digital comics and interactive media in education. For example, Laksmi and Suniasih (2021) found that digital comics used in science education significantly improved students' critical thinking and understanding of science topics by making complex concepts more accessible and engaging. Similarly, Prasetyo and Wahyudi (2021) highlighted that the use of digital comics in the classroom can increase students' motivation and learning outcomes, especially when combined with interactive features like quizzes and games.

One of the strengths of this study lies in the design of the e-comic media, which was specifically tailored to support scientific literacy. According to the OECD (2019), scientific literacy involves not only understanding scientific concepts but also the ability to apply this knowledge to real-world problems and evaluate evidence. The e-comic media in this study incorporated content, process, context, and attitudes, which are key indicators of scientific literacy. These indicators were strategically woven into the e-comic to engage students in active learning and to encourage them to think critically about scientific concepts.

1. Content: The e-comic effectively presented scientific concepts related to single substances and mixtures in a simplified manner, using clear visual representations and narratives. This aligns with research by Fatimah et al. (2019), who showed that digital comics help students grasp complex topics by making them more engaging and easier to understand.

2. Process: The interactive quizzes and activities embedded within the e-comic encouraged stu-

dents to think critically and apply their knowledge. As noted by Roswati et al. (2020), interactive learning activities significantly enhance students' ability to engage with the content and deepen their understanding of the material.

3. Context: By linking the scientific content to real-life situations, such as mixing substances in everyday environments like the kitchen, the e-comic made the learning experience more relevant and relatable for students. This approach supports the findings of Kurniawan et al. (2017), who emphasized that contextualizing scientific concepts in familiar settings improves students' ability to apply their learning outside of the classroom.

4. Attitudes: The fun and interactive nature of the e-comic media helped foster a positive attitude towards science, making students more motivated to learn. This is consistent with the results of Laksmi and Suniasih (2021), who observed that engaging, game-like learning tools increase students' enthusiasm and participation in science lessons.

The feedback from both teachers and students further validated the effectiveness of the e-comic media. Teachers reported that the media was a highly engaging tool for teaching scientific concepts, and students expressed high satisfaction with the interactive features, including quizzes, games, and the compelling narrative. These findings mirror those of Prasetyo and Wahyudi (2021), who found that digital comics significantly improved students' engagement and comprehension.

In conclusion, the findings from this study demonstrate that e-comic media based on scientific literacy is an effective tool for improving students' learning outcomes in science. By integrating interactive, engaging, and relevant content, the e-comic effectively enhanced students' understanding of single and mixed substances, fostering scientific literacy and critical thinking. This study contributes to the growing body of literature supporting the use of digital media, particularly e-comics, as an effective tool in science education. Given the positive impact of e-comics in this study, it is recommended that schools incorporate interactive media into their teaching practices to improve students' engagement and understanding of scientific concepts.

CONCLUSION

This study demonstrates that e-comic media, designed with a focus on scientific literacy, is an effective tool for improving students' learning outcomes in science education, specifically in understanding the concepts of single and mixed substances. Using a pretest-posttest experimental design, the study showed a significant improvement in students' understanding of scientific concepts after using the e-comic, as confirmed by the t-test and N-gain analysis. The medium's effectiveness was evident in the medium-level improvement (N-gain = 0.584), indicating that e-comics can significantly enhance students' ability to apply scientific knowledge and engage in scientific thinking.

The findings support the growing body of literature that emphasizes the role of interactive digital media in fostering scientific literacy. By incorporating interactive features such as quizzes, games, and engaging narratives, e-comic media not only enhanced students' understanding of scientific concepts but also promoted a positive attitude toward science learning. This aligns with previous studies (Laksmi & Suniasih, 2021; Prasetyo & Wahyudi, 2021) that suggest digital comics are effective in improving student engagement, motivation, and comprehension.

The positive feedback from both teachers and students further confirms that e-comic media is an engaging and accessible tool for science education. As a result, this study contributes valuable insights into how interactive media, such as e-comics, can be used to improve scientific literacy and learning outcomes in elementary science education. Based on these findings, it is recommended that educators incorporate e-comic media as part of their teaching strategies to enhance students' scientific understanding and foster a more engaging learning environment.

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