Enhancing Science Education with Comics: A Systematic Review of Implementation in Elementary Schools

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Abstract. This systematic review examines the integration of comics into elementary school science education, focusing on their effects on learning outcomes and practical implementation strategies. Following PRISMA guidelines, we identified 15 peer-reviewed studies published between 2019 and 2024 from Scopus, Web of Science, ERIC, and Google Scholar. Thematic analysis revealed that science comics enhance students' digital literacy, conceptual understanding, motivation, and critical thinking. Success factors include alignment of comic content with curriculum objectives, high-quality visual design, and targeted teacher training. Identified challenges comprise limited availability of rigorously developed comic materials and the risk of content oversimplification. To optimize outcomes, we propose the development of evidence-based design frameworks, integration of comics into teacher professional development, and the establishment of practical guidelines for classroom implementation. Finally, we call for longitudinal studies to assess the sustained impact of comics on science learning and to inform scalable, context-sensitive strategies.

Keywords: systematic review, digital literacy, visual learning

1 Introduction

Primary school science education is essential for establishing a strong foundation in scientific knowledge and fostering critical thinking skills in young learners from an early stage. However, science learning is often perceived as complex and tedious by elementary school students, which can inhibit their interest and motivation to learn scientific concepts [1]. Various innovative learning strategies and media have been introduced to address this challenge, including comics as a medium for teaching science[2], [3].

In the context of science learning, comics offer several unique advantages. First, comics can simplify complex scientific concepts through visual representations that are interesting and easy to understand. It is especially significant for elementary school students in the concrete operational phase of their cognitive development [4]. Second, the narrative in comics can help students connect science concepts to their everyday experiences, creating a meaningful context

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for learning [1]. Third, humor elements and interesting characters in comics can increase students' emotional engagement with the learning material, improving retention and understanding [5].

Several earlier studies have highlighted the potential benefits of incorporating comics into science education. For instance, one revealed that science comics could enhance students' conceptual grasp of intricate subjects like nanotechnology [6]. Another showed that using comics in biology instruction aids students in interpreting visual data more effectively and comprehending complex biological processes [7].

Nevertheless, despite evidence highlighting the effectiveness of comics in science education, their use at the primary school level encounters several challenges. A significant obstacle is the limited availability of high-quality science comics aligned with the curriculum [1]. There is also a concern that excessive use of comics may detract from the seriousness of learning scientific concepts [8]. Therefore, it is crucial to comprehend how comics can be successfully incorporated into science education while maintaining the depth and precision of the material.

Comics, which blend visual elements with textual storytelling, hold significant potential to engage students and convey scientific concepts more captivatingly and efficiently [1], [9]. The integration of comics in science learning has become an increasingly researched topic in recent years, with various studies showing positive impacts on student motivation, concept understanding, and learning outcomes [5], [10].

This literature review aims to analyze and synthesize findings from recent studies on using comics in science learning in primary schools, focusing on their impact on student learning outcomes and practical implementation strategies. By conducting a systematic review of empirical studies, this review aims to offer a thorough analysis of the opportunities and challenges involved in integrating comics into the elementary science curriculum. It will explore various aspects of the studies, such as research design, methodology, learning environment, comic characteristics, and key findings on the impact and effectiveness of comics. Additionally, the review will discuss the theoretical and practical implications of these findings for developing innovative science teaching strategies in primary schools. The importance of this review lies in its contribution to consolidating recent insights on the role of comics in science education. Understanding the potential, challenges, and best practices for implementing comics will enable educators and curriculum designers to make more informed decisions, ultimately enhancing the quality and effectiveness of science education at the primary level and fostering greater student engagement and interest in science from an early age.

While previous studies have explored the role of comics in secondary education, limited research synthesizes their impact and implementation in primary science education. This review addresses this gap by comprehensively analyzing recent empirical studies, contributing to the broader discourse on innovative teaching strategies.

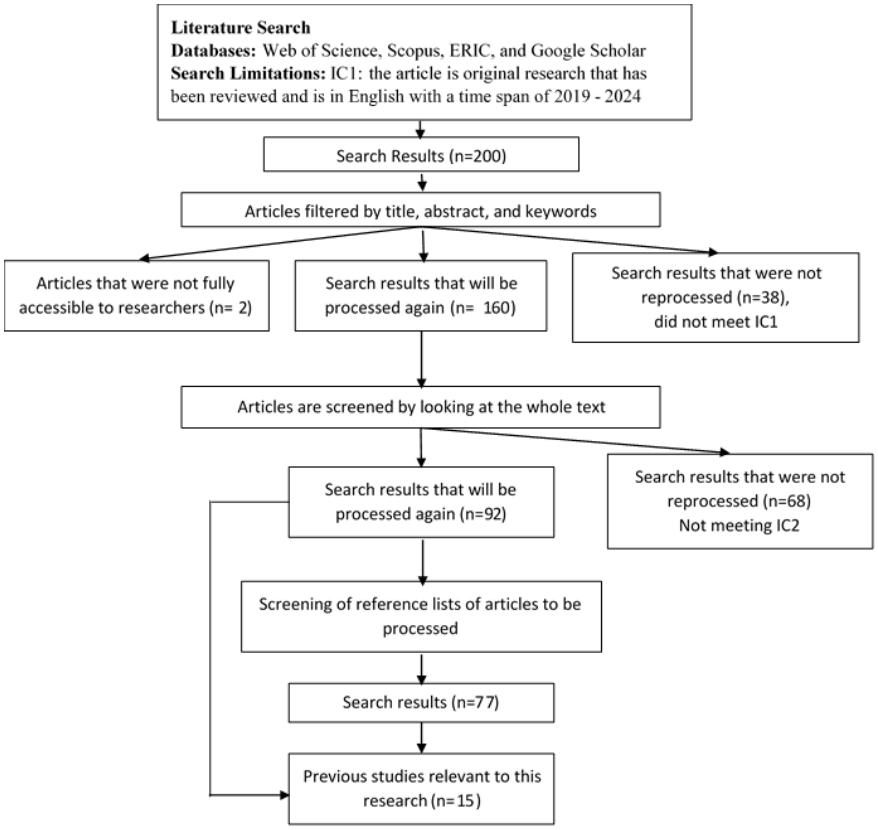
2 Method

The approach adopted for this systematic review follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure transparency, consistency, and reproducibility in the research process. By adhering to these established

standards, the review aims to provide a comprehensive and unbiased analysis, facilitating the evaluation of available evidence with straightforward, systematic reporting. This approach also enhances the credibility of the findings and allows for the replication of the study by future researchers, contributing to the reliability of the review process [11]. This method seeks to identify, assess, and analyze research outcomes about the research question, subject, or phenomenon. The Systematic Literature Review (SLR) process, grounded in the PRISMA framework, involves several phases: establishing eligibility criteria, identifying information sources, selecting literature, gathering data, and choosing data items.

The eligibility or inclusion criteria (IC) include IC1: articles are original research that has been reviewed and are in English with a period of 2019 - 2024; IC2: articles that have the purpose of using comics in science learning in elementary schools, focusing on their impact on student learning outcomes and practical implementation strategies.

Figure 1: The article search stages



The literature search process uses the Publish or Perish 8 (PoP8) assistance and will involve major electronic databases such as Web of Science, Scopus, ERIC, and Google Scholar, which will then be stored in the Mendeley tool. The keywords used in the search include a combination

of terms related to comics, science learning, learning media, and education level (elementary school) to obtain the final results of previous studies relevant to the research.

The PRISMA framework guided the systematic review, with searches conducted in Scopus, Web of Science, ERIC, and Google Scholar. Keywords included "comics," "science education," "learning media," and "elementary school." Articles were included if they focused on comics in primary science education, were peer-reviewed, and were published in English between 2019 and 2024. Thematic analysis was conducted to categorize findings into key themes: student motivation, conceptual understanding, and critical thinking.

3 Result

The search found 200 journal articles related to research on comics with a time of 2019 - 2024. The articles were screened based on their title, abstract, and keywords, leading to 2 articles that could not be fully accessed, 160 that required reprocessing, and 38 that were excluded from reprocessing as they did not meet the IC1 criteria. Then, the articles were filtered again based on the suitability of the text as a whole. Ninety-two articles would be processed to the next stage, and 68 articles were not processed because they did not meet IC2 on articles that had the purpose of using comics in science learning in elementary schools, focusing on their impact on student learning outcomes and practical implementation strategies. Screening of the reference list of 77 articles to be processed was carried out. In the end, 15 articles were obtained that were relevant to the criteria to be reviewed in this study.

Table 1: A summary of the article review

No.	Authors	Title	Subject	Method/Model	Result
1	Riwanto, M. A., & Budiarti, W. N. (2020). [12]	Development of digital science comics for elementary school as a support for digital literacy in online learning	4-grade elementary school students, elementary school teachers, media experts, material experts, and language experts	research and development research model from Borg & Gall	Digital comic media, with its strong alignment, enhances digital literacy and serves as an effective tool for online learning.
2	Liniasari, A., Yudiana, K., & Dibia, I K. (2021) [13]	Comic-based learning media with the topic of natural resources	Fourth-grade students elementary school	Research and Development	The comic-based learning media developed with natural resource content is considered valid and suitable for fourth-grade

No.	Authors	Title	Subject	Method/Model	Result
					elementary school classrooms.
3	Fatimah, S., & Fatonah, S.. (2023) [14]	Development of Focusky Multimedia-Based Comics to Increase Students' Learning Interest in Science Subjects	20 students at Rodlotut Tholibin Al-Qur'an Elementary School	Research and Development	These results were classified as "very feasible," indicating that the comics are appropriate for learning.
4	Yonanda, D. A., Yuliati, Y., & Saputra, D. S. (2019). [15]	Development of Problem-Based Comic Book as Learning Media for Improving Primary School Students' Critical Thinking Ability	28 class IV students	research and development design using an experimental research design with a one-group pretest-posttest design	This research produced a problem-based comic media product designed to meet the needs of teachers and students. The educational content in this comic addresses real-life issues relevant to the students' environment. The results are excellent and can be used for learning.
5	Mustikasari, L., Priscylio, G., Hartati, T., & Soandi, W. (2020) [16]	The development of digital comic on ecosystem for thematic learning in elementary schools	Fifth-grade students from five public, two private, and two integrated Islamic elementary schools participated.	research and development	Digital comics can increase student motivation and engagement, inspire and make them an effective teaching aid.
6	Syarah, E. S., Yetti, E., Fridani, L., Yufiarti, Y., Hapidin, H., & Pupala, B. (2019) [17]	Electronic comics in elementary school science learning for marine conservation	Students in elementary school, aged 6 to 8 years old.	Quasi-experimental design model with paired t-test statistical analysis	The results showed a significant increase in knowledge, students were more interested in the electronic comics,

No.	Authors	Title	Subject	Method/Model	Result
					and students could better identify and understand the concepts.
7	Sukri, A., Rizka, M. A., Sakti, H. G., Harisanti, B.M., & Muti'ah, A (2020) [18]	The effect of local primacy-based comic media on students' conservation attitudes	52 students from two experimental schools	quasi-experimental research that adopts and modifies a split sample pretest-posttest design	The results of this study suggest that comic media based on local wisdom can improve students' conservation attitudes.
8	Priyangga, B., Sarwi, S., Widiyatmoko, A., et al. (2022). [19]	Development of e-comic based on local wisdom to improve scientific literacy	Fourth grade elementary school students	Research and Development	The validator test results, categorized as highly valid, indicate that the e-comic media based on local wisdom is suitable for teaching alternative energy sources in fourth-grade elementary school science lessons.
9	Pantaleo, S. (2021). [3]	Elementary students meaning-making of the Science Comics series by First Second.	4th and 5th grade students	Qualitative descriptive research	These results suggest that students' understanding of the what, why, and how of design impacts their aesthetic appreciation and critical thinking regarding science graphic novels.
10	Udayani, N., Wibawa, I. M. C., & Ratri, W. (2021) [20]	Development Of E-Comic Learning Media On The Topic Of The Human Digestive System	two media experts, two material experts, and two practitioners	Research and Development	Therefore, the e-comic learning media on the human digestive system topic is valid and qualified.
11	Wicaksono, J. W., Japar, M.,	Development of Digital Based Comic	30 fifth-grade students	Qualitative descriptive research	The research findings indicate a strong need to

No.	Authors	Title	Subject	Method/Model	Result
	& Utomo, E. (2021) [21]	Media for Primary V-Class Student Learning	Elementary School		develop digital-based comic media.
12	Lamminpää, J., Vesterinen, V. M., & Puutio, K. (2023) [22]	Draw-A-Science-Comic: exploring children's conceptions by drawing a comic about science.	104 students aged 8-13 years	Qualitative descriptive research	Comics can portray scientific activities well. Interesting stories in comics can express emotions and attitudes related to science.
13	Burhanudin, F., Susilowati, S. M. E., & Haryani, S (2019) [23]	Development of Human Skeleton Comic to Enhance Students' Motivation and Science Learning Outcomes	5th grade at Mahad Islam Elementary School	Research and Development	Comic-based teaching materials on the human skeleton in science are valid and effective, benefiting students by promoting creativity, innovation, and fun.
14	Rusydiana, U., Widodo, W., & Suprapto, N. (2023) [24]	The development of picture story book to improve the science literacy skills of grade 4 elementary school student	Thirty fourth-grade students were assigned to the control group, and another thirty to the experimental group.	R&D with a static group pretest-posttest design.	Picture storybooks and accompanying tools are valid, practical, and effective tools for enhancing scientific literacy skills.
15	Rutta, C. B., Schiavo, G., Zancanaro, M., & Rubegnia, E., (2019) [25]	Comic-based digital storytelling with primary school children	12 students in elementary school	Case Study Research	Comics increase student involvement and communication in learning

3.1. Enhancing Visual Literacy

Integrating comics in science learning significantly enhances students' visual literacy skills. Visual literacy is crucial in science education, given the reliance on diagrams, charts, and other

visual media to communicate complex information. Comics serve as an effective tool to engage students with visual elements, helping them better interpret and analyze scientific data.

Studies revealed that students exposed to science comics demonstrated improved comprehension of visual representations, such as diagrams and processes, compared to traditional methods [26], [27]. Comics provide dual engagement with text and imagery, enabling students to connect abstract scientific concepts with concrete visual elements. For example, comics focused on ecosystems and conservation helped students visualize interdependencies in nature effectively [16], [17].

3.2 Improving Conceptual Understanding

Comics play a critical role in helping students grasp complex scientific concepts by combining visuals and narratives to make abstract ideas more accessible. Dual Coding Theory [28] explains how combining verbal and visual channels strengthens memory retention and comprehension. Comics use this dual modality to simplify complicated topics like the human digestive system or alternative energy sources [19], [20].

Students demonstrated a deeper understanding of science topics when taught using problem-based comic books, as evidenced by significant pretest-posttest improvements in critical thinking [15]. In another study, digital science comics on nanotechnology enhanced students' ability to connect theoretical principles to real-world applications [10].

3.3 Motivating Students

Comics effectively increase students' motivation and interest in learning, making science more approachable and engaging. The use of colorful visuals, relatable characters, and humor in comics fosters an emotional connection, reducing anxiety and building confidence in learning challenging subjects like science [5], [8].

Students who used comics reported greater enjoyment and willingness to engage with scientific material than students who used traditional textbooks [12]. For example, electronic comics about marine conservation significantly improved students' interest and engagement in learning environmental topics [17]. Self-determination theory [29] supports these findings by explaining how comics promote intrinsic motivation through autonomy and competence.

3.4 Supporting Aesthetic Understanding and Critical Thinking

Comics encourage students to develop an appreciation for artistic elements and foster higher-order thinking skills through storytelling and problem-solving tasks. Comics in science education contribute to developing students' aesthetic appreciation and critical thinking skills. By combining artistic elements with educational content, comics engage students in analyzing the material's visual and textual aspects.

Exposure to diverse art styles in comics helps students develop an appreciation for visual design elements, such as color, composition, and narrative structure. A study by Berkowitz and Packer (2001) showed that using comics in art education improved students' ability to analyze visual artworks, a skill transferable to understanding science illustrations [30]. Science comics use visual storytelling to convey concepts in a way that fosters students' aesthetic sensibilities and creativity, particularly in designing their science-related comics [22].

Comics require students to make inferences and interpret complex ideas presented in both visual and textual formats. For example, students analyzing problem-based science comics were found to improve their critical thinking and reasoning skills, as they had to connect storylines to scientific principles [15]. This integration of narrative and visuals encourages students to ask questions, solve problems, and engage in reflective thinking, which is essential for science education.

Several comic-based learning activities help students synthesize knowledge and express their understanding creatively, such as creating students' science comics [25]. By engaging with the storyline, characters, and themes of comics, students practice skills such as making predictions and evaluating scientific concepts critically [3].

4 Discussion

Comics are a versatile and engaging form of media that can effectively enhance elementary school learning activities. By combining visual elements with text, comics provide an interactive way for students to grasp complex concepts and improve their comprehension. Comics in education allow for the integration of creativity and storytelling, which can captivate young learners' attention and encourage active participation. Additionally, comics can be particularly beneficial in subjects such as science, language arts, and social studies, as they simplify complex ideas and make learning more accessible and enjoyable. Through their ability to present information in a visually appealing and easy-to-understand format, comics can support various learning styles, promote critical thinking, and foster a deeper connection to the material being taught. Based on the literature review, comics turned out to be:

4.1 Create Digital-Visual Literacy

Integrating comics in science learning offers significant benefits in developing students' visual literacy skills. Visual literacy is essential in science education, mainly due to the overwhelming amount of scientific information often conveyed through visual media, such as diagrams, graphs, charts, and models. In this context, science comics effectively engage students with visual elements, enabling them better to understand complex concepts [25] [30]. By incorporating both text and imagery, science comics not only make learning more accessible but also enhance students' ability to interpret and analyze visual data. This dual engagement with both narrative and visual content helps students develop critical thinking skills, enabling them to connect abstract scientific ideas with concrete visual representations, thus fostering deeper comprehension and retention of scientific knowledge. Moreover, by regularly interacting with science comics, students can improve their ability to decode and critically evaluate various forms of visual communication. This skill is increasingly important in today's information-rich, visually oriented world.

Research demonstrated that students regularly exposed to science comics exhibited a significant improvement in their ability to comprehend and interpret visual representations of scientific concepts [27]. This finding highlights the potential of comics as a powerful educational tool for enhancing students' understanding of complex scientific ideas and fostering the development of visual literacy skills. Visual literacy, crucial in science education, enables students to decode, analyze, and critically assess various forms of visual data, such as diagrams, charts, and

illustrations. By incorporating comics into the learning process, educators can provide students with a more engaging and accessible way to develop these essential skills, which are increasingly important in a world that is becoming more visually oriented. Therefore, using comics in science lessons may serve as an innovative approach to support the development of conceptual understanding and visual literacy, ultimately improving students' overall learning experience.

4.2 Bring Out the Understanding of Science Concepts

Integrating comics in science education at the elementary level can significantly enhance students' comprehension of concepts by providing a dynamic and engaging approach to learning. Science comics help students visualize abstract ideas, making complex topics more accessible and easier to grasp. Comics offer a unique way to illustrate scientific principles through the combination of visuals and text, enabling students to connect theoretical knowledge with real-world examples [10]. This multimodal learning experience supports better retention and encourages deeper critical thinking and problem-solving skills, fostering a more profound understanding of scientific concepts. A study conveyed that science comics helped pre-service teachers develop essential content simplification and narrative construction skills, making them more adept at creating engaging science lessons [2].

The effectiveness of comics in enhancing the understanding of science concepts can be understood through dual coding theory [28], which posits that information is processed and stored in two distinct channels: the verbal channel, which processes linguistic information, and the non-verbal channel, which processes visual information. By combining both verbal and visual elements, comics enable learners to engage both cognitive channels simultaneously, promoting better retention and comprehension. This integration of text and images allows students to create mental connections between concepts, making abstract or complex science topics more accessible and easier to understand. Furthermore, dual coding theory suggests that learners who process information through both modalities are more likely to form durable memory traces, facilitating long-term understanding of scientific principles. This theory suggests that presenting information visually and verbally simultaneously can enhance cognitive processing and improve memory retention. Comics, combining images and text, allow students to process information through two cognitive channels, thus strengthening their understanding of science concepts.

4.3 Build Student Motivation and Interest

The integration of comics into science education has significantly enhanced students' motivation and interest in learning, providing an engaging and dynamic approach to traditionally challenging subjects. Students who engaged with science comics demonstrated higher levels of involvement and excitement than those using conventional teaching methods, highlighting the potential of comics to captivate students' attention and foster deeper engagement [5]. That aligns with the findings that science comics can transform learning experiences by making complex concepts more approachable and enjoyable. Furthermore, visual storytelling in comics has been shown to reduce students' anxiety, particularly in subjects that students often perceive as complex, such as scientific theories and principles [8]. By combining humor, relatable characters, and visual elements, comics offer a unique medium for simplifying abstract ideas, helping students build confidence and a more positive attitude toward learning science.

This increase in motivation and interest in learning can be explained through self-determination theory [29]. Science comics present the material in a more engaging format and are relevant to student's daily lives[32], thus increasing their sense of autonomy and competence in learning science. That, in turn, can encourage students' intrinsic motivation to learn science concepts.

4.4 Lead to Aesthetic Understanding and Critical Thinking

Through exposure to various visual art styles, comics foster students' aesthetic sensibilities. In comics, the use of color, composition, and design enhances the appreciation of artistic elements. Students hone their visual literacy skills by understanding the meaning of images. A study showed that using comics when teaching art improved students' ability to analyze and appreciate visual artworks [30]. Students are invited to consider comics' storylines, characters, and themes because the stories are complex. Reading comics involves making inferences from visual and textual information, which helps improve critical thinking skills[33], [34]. Research suggests that comics can be utilized in biology instruction to enhance students' conceptual understanding and foster their critical thinking abilities [8].

4.5 Create Engagement and Communication

Comics provide a visually engaging format that captures students' attention and encourages them to participate actively in the learning process. Combining vivid illustrations, dynamic layouts, and concise text helps simplify complex concepts, making them more accessible and easier to understand. By incorporating relatable characters and stories, comics can create an emotional connection, fostering a more profound sense of engagement [35] and motivation. This interactive approach enhances comprehension and stimulates creativity and critical thinking, encouraging students to explore ideas and make connections beyond the classroom. Additionally, comics offer an enjoyable learning experience, which can increase students' retention and enthusiasm for the subject matter.

Comics help students develop skills in interpreting and conveying information through various mediums by integrating visual and verbal elements. This unique combination enhances their understanding of the content and promotes creativity and critical thinking. Additionally, including comics in educational discussions can facilitate verbal communication in the classroom, creating an interactive environment where students can share their ideas and thoughts more effectively. According to Hosler and Boomer, such discussions can further deepen students' engagement and comprehension, allowing them to connect with the material on multiple levels and improving their overall learning experience [8].

Despite the many benefits, implementing comics in science learning in elementary schools also faces some challenges. Tatalovic identified several potential problems, such as the risk of oversimplification of science concepts, a mismatch between comic style and learning objectives, and limitations in material coverage. To overcome these challenges, some researchers emphasize the importance of carefully designing science comics and collaboration between science experts, educators, and comic artists [1]. Farinella suggested an evidence-based approach in the development of science comics, taking into account instructional design principles and cognitive learning theory [9].

5 Conclusion

This systematic review shows that integrating comics in science learning in primary schools can improve digital-visual literacy, deepen the understanding of science concepts, increase student motivation and interest, and enrich aesthetic understanding and critical thinking. In addition, the use of comics can also strengthen student engagement and communication. However, effective implementation requires careful consideration of comic design, learning context, and student needs. Further research is needed to explore the long-term effectiveness of using science comics and develop practical guidelines for educators in integrating comics into science learning in elementary schools.

Beyond the outlined benefits, it is important to acknowledge that challenges exist. Comic designs must be engaging, relevant, and aligned with the applicable curriculum. Furthermore, the varying learning contexts at each school and students' diverse abilities need to be considered. In further research, these aspects need to be explored in greater depth to ensure that comics truly provide a sustainable positive impact on science learning.

Moreover, professional development for teachers in designing and using science comics is significant. This will help teachers understand how to design compelling comics and integrate them into existing learning strategies. Additionally, the formulation of practical guidelines for educators can provide clear and structured directions, helping them plan and implement comic-based science learning more effectively. Future research is expected to produce comprehensive and applicable guidelines to optimize the benefits of comics in science education at elementary schools.

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