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Bringing Numbers to Life through Numeracy Literacy: Practical Use of E-Comic Media in Early Education

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Abstract

This research aims to develop and assess the effectiveness of e-comic media as a literacy-numeracy learning tool for early childhood education, specifically in helping children distinguish letters *b*, *d*, and *p*. This study employed a research and development (R&D) approach using the Borg and Gall model. The media were validated by early childhood experts, linguists, users (teachers), and media experts, followed by field implementation in PAUD Pembina 7 Ternate City. The participants included 25 children aged 5–6 years, selected based on their difficulty recognizing the targeted letters. Expert validation results showed high feasibility, with average scores of 84% (material experts), 93.4% (linguist), 95.4% (teachers), and 82% (media expert), indicating that the media met the developmental, linguistic, and technical criteria. Field trials, including limited and operational tests, showed strong student engagement, with response scores of 83.71% and 88.86%, respectively, in limited trials, and 90.02% in the operational test. The children showed enthusiasm, understood the storyline, and were able to differentiate letters effectively after viewing. These findings suggest that e-comic media is an effective, engaging, and developmentally appropriate tool for improving early literacy and numeracy. The use of animated storytelling, visual cues, and moral values in videos supports both cognitive and character development in young learners. This study recommends integrating multimedia learning tools in early education and encourages further development and research on similar digital media for broader educational contexts.

Keywords: early childhood education, e-comic media, literacy and numeracy, letter recognition, multimedia learning, animated story, child development

1. Introduction

In recent years, there has been an increasing recognition of numeracy literacy—the capacity to understand and use numbers and symbols in context—as a foundational competency in early education (Herman et al., 2022; Sinamo et al., 2023; Nafila et al., 2025). Numeracy literacy is not merely about computation; it involves interpreting real world data, solving practical problems, and reasoning mathematically within social contexts. For young learners, especially in the early elementary years, developing such skills can profoundly influence later academic success and everyday functionality. However, many students struggle to develop early numeracy skills because of disengagement, lack of contextual learning, and the abstract nature of early math instruction.

Simultaneously, emerging literacies, including visual and digital literacies, are increasingly recognized as critical to children's learning in a multimedia-rich society (Lestari & Ahmadi, 2021; Saqinah & Yuliantina, 2024). Children are increasingly immersed in visual culture—comics, animations, videos, and interactive media—all of which play an important role in shaping how they process and retain information (emergent literacy frameworks). Visual media, such as comics, in particular, offer a compelling platform: by pairing images with a narrative structure, they engage multiple cognitive pathways and support both comprehension and recall (Ansari et al., 2023). This makes comics not only a tool for literacy development but also a potential bridge to numeracy literacy, especially in the early grades.

This shift has led to a growing interest in **e-comics**—digital, interactive versions of comics—as pedagogical tools in classrooms. Studies have demonstrated that e-comics designed around mathematical topics can foster literacy and numeracy skills by embedding mathematical concepts in relatable characters and real-world situations (Siagian et al., 2021; Manurung et al., 2025). Their ability to blend interactivity, visual storytelling, and contextual learning makes them particularly effective for young learners who often find traditional math instruction inaccessible.

Despite this promise, a significant gap remains in the integration of e-comic media specifically targeted at early numeracy development. Much of the existing research on math comics or digital storytelling has focused on upper elementary and secondary levels or general literacy enhancement (Purwoko et al., 2023; Elder, 2011). Systematic reviews, such as those by Nafila et al. (2025), confirm that while comics have been used to support math learning, few studies have explored their practical classroom implementation for numeracy literacy in early education settings, particularly among students aged 5–8. Moreover, few studies have comprehensively investigated the design, adaptation, and evaluation of these tools in diverse learning environments (Yulaichah et al., 2023).

This phenomenon is particularly concerning given the persistent numeracy gaps seen in early learners across global education systems. According to early assessment data and classroom observations, many students enter grade levels without mastering foundational skills such as counting, number recognition, and basic operations. These foundational deficits often lead to long-term mathematical difficulties. Educators are urgently seeking innovative, accessible, and engaging tools that can bring abstract concepts to life and meet children at their developmental level, both cognitively and emotionally (Resmi et al., 2023).

Recent interventional studies have offered a promising direction. For example, Aprilia et al. (2023) developed a STEM-based e-comic to teach probability, showing strong validation and positive impacts on students' understanding. Similarly, comics grounded in local cultural narratives, such as those by Purwoko et al. (2023), have helped to bridge abstract concepts with learners' lived experiences. These innovations suggest that culturally relevant and developmentally appropriate e-comics can be strategically designed to promote numeracy literacy from the early grades. However, more research is needed to test their effectiveness at the scale and to develop best practices for classroom use.

This study aims to address this gap by exploring how e-comic media can be practically applied to enhance numeracy literacy in early education. It will examine pedagogical design strategies, review evidence of their effectiveness, and offer guidance on implementation. In doing so, it contributes to both scholarly literature and the practical toolkit of early childhood educators, curriculum designers, and policymakers committed to equitable and engaging numeracy development.

2. Literature Review

2.1 Numeracy Literacy Foundations in Early Childhood

Early numeracy literacy extends beyond rote computation to include the understanding of numerical concepts in meaningful contexts. Soto-Calvo et al. (2020) showed that preschool home-learning experiences, particularly code-focused activities such as counting games and number-based interactions, significantly predict number skills at school entry even when controlling for other cognitive abilities. This underscores the importance of early, contextual engagement with numbers as the foundation for later mathematics learning.

2.2 Role of Digital Storytelling and Multimodal Media

Digital storytelling has been shown to effectively support early mathematics learning, especially for students with the learning differences. Altındağ Kumaş (2024) conducted an eight-week digital story intervention for kindergarteners with mild intellectual disabilities and found significant gains in early math skills and engagement as measured by TEMA-3 scores. By blending text, visuals, and narration, such approaches align well with multimodal cognitive pathways relevant to numeracy development.

2.3 Effectiveness of E-Comics and Digital Comics

Siagian et al. (2021) investigated a literacy and numeracy e-comic designed for primary classrooms and concluded that these media could enhance reading, number recognition, and contextual numeracy understanding in both formal and informal settings. Fatmawati (2025), via a literature review of prior studies, affirmed that digital comics significantly increased student motivation, engagement, and learning outcomes in mathematics contexts

2.4 Design and Impact of Interactive Digital Comics

More focused on numeracy improvement, Ningrum, Basir, & Maharani (2023) developed a digital comic specifically for teaching statistics that achieved high validity (89.7 %) and practicality in both student and teacher responses (over 86 %). Their development used the ADDIE model and included expert validation, demonstrating that digital comics can be systematically designed to support statistical numeracy with strong pedagogical credibility. Similarly, Purwoko,

Purwaningsih, & Nuryadi (2023) created ethnomathematics-based interactive e-comics oriented toward numeracy skills for junior high students. The media were found to be valid, practical, and effective in improving numeracy skills after implementation. Though focused on older learners, its design principles (cultural relevance, and interactivity) suggest applicability to younger learners. Yuliani & Setiawan (2024) introduced flipbook-style digital comics to enhance learning on simple topics and found statistically significant improvements in student comprehension and engagement with content. Although not explicitly numeracy-focused, their design offers useful insights into pacing, interactivity, and visual sequencing relevant to early education.

2.5 Integration with Pedagogical Models and Teacher Acceptance

Incorporating digital media such as e-comics into early education requires both teacher readiness and pedagogical coherence. A study in Saudi Arabia using the Technology Acceptance Model (TAM) assessed pre-service early childhood teachers' acceptance of digital storytelling, comics, and infographics. It was found that perceived usefulness and perceived ease of use predicted intent to use these media, which in turn influenced attitudes and actual acceptance. This highlights the need to address teacher beliefs and training when introducing e-comics in early classrooms.

2.6 Theoretical Basis: Cognitive and Multimedia Learning Principles

Multimedia frameworks, such as Dual Coding Theory and Cognitive Theory of Multimedia Learning, support the use of visual-textual media in learning. While not tied to e-comics in these studies, Sinclair & Baccaglini-Frank (2016) reviewed early primary school use of digital technologies and emphasized that tools that combine visual, tactile, and narrative elements facilitate mathematical expression and understanding in K–2 classrooms.

2.7 Gaps and Limitations in Current Literature

Although these studies have provided valuable evidence, substantial gaps persist. Most research focuses on older children (elementary or middle school), with limited exploration of e-comics in the early years (ages 5–8). Details on classroom integration, scaffolding by teachers, pacing controls, and the long-term effects of e-comic interventions remain under-examined. Furthermore, few studies have sought to confirm teacher acceptance, classroom feasibility, or sustained numeracy literacy outcomes in the early education contexts.

3. Research Method

3.1 Research Design

This study employed a Research and Development (R&D) approach to achieve the research objectives in accordance with problem formulation. Specifically, the Borg and Gall R&D model was used as the framework for this study. This model systematically guides the development and validation of educational media and tools through iterative cycles of design, testing, and refinement (Borg & Gall, 1983; Cahyani et al., 2025).

3.2 Data Source

This research was conducted at PAUD Pembina 7, located in Tubo Village, North Ternate District, Ternate City, North Maluku Province. The study involved 25 students as research subjects, consisting of 12 boys and 13 girls aged 5 to 6 years. These students were purposively selected based on specific criteria: children who did not recognize the letters 'b,' 'd,' and 'p,' ensuring the effectiveness of the media developed. Parental permission was obtained before participation. The choice of this institution was influenced by the availability of adequate infrastructure to facilitate the trial and completion of the Literacy-Numeracy e-comic media development.

3.3 Data Collection Method

The data collection methods included questionnaires, interviews, and documentation to obtain comprehensive and reliable data. The research instruments were designed and administered to gather quantitative and qualitative data relevant to the study objectives. The instruments included Likert-scale questionnaires and evaluation guidelines developed from feasibility tests conducted by media experts, subject-matter experts, and student feedback.

3.4 Data Analysis Method

The data analysis employed both quantitative and qualitative descriptive techniques. Quantitative data from Likert-scale instruments were analyzed using a 5-point achievement scale to determine the qualifications of the developed e-comic media. Qualitative data from observations, interviews, and documentation were descriptively analyzed to complement the quantitative findings (Sinaga et al., 2025). The final goal was to validate and prepare the e-comic media for practical use in enhancing early childhood education, particularly in recognizing the letters 'b,' 'd,' and 'p.'

Table 1. Conversion of Level of Achievement Scale 5

Achievement Rate (%)	Assessment Scale	Qualification	Description
90%-100%	4,51-5.00	Highly Appropriate	No revision needed
75%-89%	3,51-4,50	Appropriate	Minor revision
65%-74%	2,51-3,50	Neutral	Revise as necessary
55%-64%	1,51-2,50	Not Applicable	Many aspects need revision
0%-54%	1-1-50	Highly Not Applicable	Redo the product

(Tegeh & Kirna, 2013)

3.5 Assessment of Children's Response Through Observation

Children's responses were observed and categorized based on the following aspects and indicators:

Table 2. Aspects for Assessment of Children's Response Through Observation

Aspect	**Indicators**
1. Children's enthusiasm for learning	- Child's response when watching the show- Motivation in learning (interest)
2. Ability to distinguish the letters b, d, and p	- Ability to correctly identify the letters b, d, and p
3. Ability to understand the content	- Ability to retell the story content- Ability to answer questions related to the content

4. Results

The research process began with initial observations, followed by a thorough validation phase, involving multiple expert groups and end-users. The e-comic media was evaluated by material experts specializing in early childhood education (PAUD experts), linguists, users (teachers), media experts, and through direct assessment of children's responses during the playback of the e-comic video.

A. Expert Validation

1. Material Experts (PAUD Experts):

Material experts assessed the e-comic content by focusing on its alignment with child development principles and the appropriateness of the learning materials for early childhood education. Their evaluation confirmed that the media's content supported developmental milestones and was suitable for the target age group.

2. Linguistic Experts

Linguists reviewed the media to ensure conformity with the Indonesian language rules, emphasizing clear communication and effective interaction. This was important to guarantee that the language used in the e-comic was accessible and comprehensible for young learners.

3. User (Teacher) Assessment

Two teachers participated as users to evaluate the media in terms of its relevance and effectiveness in facilitating child development and learning. Their feedback highlighted the practical applicability of media in classroom settings.

4. Media Expert Assessment

A media expert specializing in animation and educational media evaluated e-comic based on visual design, text message clarity, image quality, and animation effectiveness. Feedback highlighted several areas for improvement, such as the need for more concise content and relatable examples beyond fruit illustrations. Specific animation elements, such as inconsistent ant movements and green-screen effects on the ant's antenna, were noted as distracting and in need of refinement. Furthermore, the media expert emphasized that the primary medium was video animation rather than a traditional static e-comic, which require adjustments in design and delivery.

5. Children's Response Assessment

The children's responses were assessed using a sample of 10 children observed by three independent observers. Seven indicators were used to evaluate the children's engagement and learning outcomes:

1) Sitting quietly during the media presentation
2) Enthusiastically asking questions
3) Ability to distinguish the letters 'b,' 'd,' and 'p'
4) Ability to retell the contents of the e-comic story
5) Understanding of the story's message

6) Preference for the animation style
7) Interest in watching the media again

Overall, the observations indicated positive responses, with children showing increased enthusiasm and comprehension after exposure to the e-comic video.

6. Media Revision and Final Validation

Based on comprehensive feedback, the researchers revised the e-comic video to address the suggested improvements. Revisions included simplifying examples, refining animations, and enhancing the clarity and conciseness of content. The updated e-comic video underwent a second round of validation, which concluded that the media was suitable for use with only minor revisions required for future iterations.

The revised version of the e-comic video was tested in both limited small-group settings and classical groups at PAUD Pembina 7 Ternate City, confirming its effectiveness as a tool for enhancing early childhood literacy and numeracy skills.

Figure 1. Product Visualization of e-comic Video

The e-comic video was specifically designed to help young children recognize and differentiate the lowercase letters 'b,' 'd,' and 'p.' The narrative unfolds in a vibrant forest setting featuring two ant characters: Sangdo and Yongpil. In the story, Sangdo brings a single cherry to Yongpil, who immediately desires as many cherries as possible. However, Sangdo kindly explained the importance of sharing the cherries fairly with their fellow ants, teaching Yongpil a valuable lesson about generosity and avoiding greed.

Throughout their conversation, the ants observe the cherries closely and notice that their shapes resemble the lowercase letters 'b,' 'd,' and 'p.' This connection is illustrated by showing how the cherry stems resemble the letter shapes when viewed from different angles—moving the stem to the left forms a ‘b,’ to the right forms a ‘d,’ and turning the cherry upside down reveals the letter ‘p.’ This creative visualization helps children associate familiar objects with letter shapes, making the learning experience more engaging and memorable.

At the conclusion of the story, a clear moral message was conveyed, encouraging children to practice sharing and kindness rather than selfishness. Additionally, the video reinforces letter recognition by emphasizing how to distinguish between the often-confused letters 'b,' 'd,' and 'p.' The story closes with an energetic and colorful alphabet song featuring lively animations of letters, providing a joyful and interactive way to reinforce the literacy lesson. This combination of storytelling, moral education, and visual letter recognition makes the e-comic video a practical and effective tool for early childhood literacy and numeracy development.

B. Expert Validation Results

The validation of the Literacy-Numeracy e-comic video was carried out by four categories of experts: early childhood (material) experts, linguists, early childhood teachers (as users), and media experts. Each participant provided a structured assessment based on relevant aspects and indicators tailored to their areas of expertise.

1. Material Expert (Early Childhood Expert) Validation

The early childhood expert evaluated the content across two core aspects: child development and quality of learning materials. Each aspect included multiple indicators (nine indicators in total). The child development aspect achieved a perfect average score of 5.0, indicating an excellent alignment with early childhood developmental needs. The learning material aspect had an average of 4.09. These scores yielded a combined average of 4.2, which translates to 84%, placing the media in the "very good" category. These results affirm that the content is developmentally appropriate and effectively supports early childhood learning goals.

2. Linguist Validation

The linguist reviewed two aspects of e-comic videos: adherence to standard Indonesian language rules and the media's communicative and interactive qualities. Both aspects received a high average score of 4.67, resulting in a combined average of 4.67 or 93.4%, respectively. This demonstrates that the media is both linguistically accurate and engaging for its young audience. The use of language is not only correct but also accessible and stimulating for early learners.

3. Teacher (User) Validation

Two early childhood education teachers assessed the media using two aspects: child development and instructional material quality, supported by nine indicators. The child development aspect scored a perfect 5.0, while the learning material aspect received 4.73. The combined average was 4.77, translating to 95.4%, indicating that the media are exceptionally well-suited for classroom use, both in terms of content accuracy and developmental alignment.

4. Media Expert Validation

One media expert assessed the video using three key dimensions: display design, message (text and image) design, and animation. With 13 indicators, the scores were as follows:

1) Display design: 4.0
2) Text message design: 4.2
3) Image message design: 3.67
4) Animation and material design: 4.14

The overall average score was 4.1, which translates to 82%, placing it in the "very good" category. The media were deemed suitable for implementation, although minor revisions, such as improving image clarity and animation smoothness, were recommended.

Table 3. Summary Table of Expert Validation

Expert Type	**Aspect Evaluated**	**Average Score**	**Percentage (%)**	**Evaluation Result**
Material Expert	Child Development	5.00	100%	Excellent
	Learning Material	4.09	81.8%	Very Good
	Overall Average	**4.20**	**84.0%**	Very Good
Linguist	Language Rules	4.67	93.4%	Excellent
	Communicative & Interactive Media	4.67	93.4%	Excellent
	Overall Average	**4.67**	**93.4%**	Excellent
Teacher (User)	Child Development	5.00	100%	Excellent
	Learning Material	4.73	94.6%	Excellent
	Overall Average	**4.77**	**95.4%**	Excellent
Media Expert	Display Design	4.00	80.0%	Very Good
	Text Message Design	4.20	84.0%	Very Good
	Image Message Design	3.67	73.4%	Good
	Animation and Material Design	4.14	82.8%	Very Good
	Overall Average	**4.10**	**82.0%**	Very Good

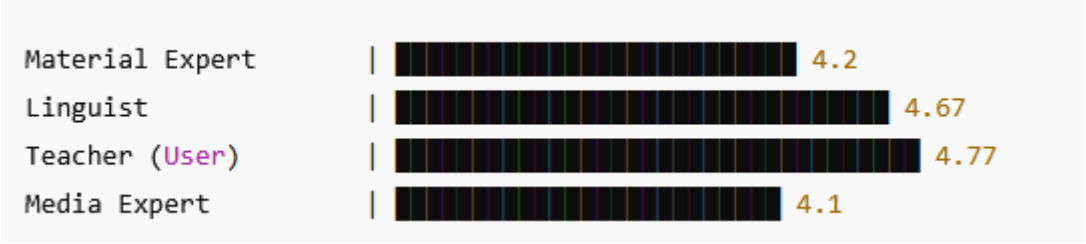

Figure 2. Manual Bar Chart of Overall Validation Scores (Note: Each ▉ represents approximately 0.2 on a 5-point scale)

C. Field Testing and Operational Trial Results

To evaluate the effectiveness and practicality of the developed e-comic media, a series of field trials were conducted at PAUD Pembina 7, Ternate City, focusing on children in Group B. The testing process was divided into two main phases: a limited field test and a full operational (classical) test. Each trial involved observing children's responses using structured guidelines that covered seven behavioral and cognitive indicators:

1) Children sit quietly while listening
2) Children express enthusiasm by asking questions
3) Children are able to distinguish between the letters 'b,' 'd,' and 'p'
4) Children can retell the story's content
5) Children understand the message of the story
6) Children enjoy the story content
7) Children show interest in watching the video again

1. Limited Field Test

The limited field test was conducted in two stages:

1.1 First Trial (April 30, 2024)

A small group of six children from Group B was selected, representing a range of intellectual abilities (high, medium, and low), as determined by their teachers and school administrators. The children viewed the e-comic video using a laptop and an LCD projector. Subsequently, their responses were measured using a seven-indicator observational guide. The results showed that the students' average response score was 83.71%, which fell into the "Good" category. This indicated that the children were generally engaged and receptive to media.

1.2 Second Trial (May 7, 2024)

In the second stage of the limited trial, ten children from Group B and were participated, again selected across varying levels of ability. The viewing conditions remained the same, with students watching the e-comic video via LCD projection, accompanied by their class teacher. The observation data collected showed a higher average response score of 88.86%, maintaining the "Good" category, reflecting increased engagement and comprehension.

When the results from both sessions were averaged, the limited field trial produced an overall response score of 86.28%, reinforcing that the media is well-received and educationally effective in smaller group settings.

2. Operational Field Test (Classical Test)

The final testing phase was the operational trial, conducted on May 10, 2024, involving the entire Group B class of 25 children. In this larger setting, students watched the e-comic video in a classroom environment with guidance from both the teacher and researcher. The children's engagement was closely monitored and assessed using the same seven-indicator framework.

The operational test produced an average response score of 90.02%, placing it in the "Excellent" category. Observations revealed that the students were enthusiastic about learning through e-comic media. Importantly, the majority of the children demonstrated a clear ability to correctly differentiate the letters 'b,' 'd,' and 'p' after the session, indicating that the media was not only engaging but also effective in achieving its literacy objectives.

Table 4. Summary Chart: Student Response Results from Field Tests

Trial Type	Date	Number of Children	Average Response Score (%)	Qualitative Category
Limited Test (Stage 1)	April 30, 2024	6	83.71%	Good
Limited Test (Stage 2)	May 7, 2024	10	88.86%	Good
Average of Limited Test	—	—	**86.28%**	**Good**
Operational Test	May 10, 2024	25	90.02%	Excellent

Figure 3. Manual Bar Chart: Student Response Results

5. Discussion

The results of this study demonstrate that the development and implementation of e-comic media in early childhood education can significantly enhance literacy and numeracy learning outcomes, particularly in recognizing and distinguishing similar letters such as *b*, *d*, and *p*. The findings support the notion that integrating digital media with educational storytelling not only improves cognitive recognition skills in young learners, but also sustains their attention, motivation, and overall enjoyment during the learning process.

1. Alignment with Child Development Principles

Validation by early childhood education experts confirmed that e-comic content is highly appropriate for developmental needs. With a combined average expert score of 84%, the media effectively aligned with age-appropriate learning goals. Moreover, feedback from early childhood educators (users) was even more encouraging, with an average of 95.4%, indicating that the media were both relevant and usable in real classroom settings. These findings reinforce the argument made by Piagetian and Vygotskian theories of learning, where children benefit most from developmentally appropriate practices and interactive learning environments (Berk & Winsler, 1995).

2. Linguistic and Visual Communication Effectiveness

Linguist assessments yielded an average score of 93.4%, reflecting high standards for both language accuracy and communicative clarity. The content uses familiar vocabulary and accessible phrasing while also embedding a moral narrative that reinforces character education. Additionally, linguistic interactivity—encouraging children to ask questions and retell the story—proved effective in both limited and operational trials. These linguistic attributes align with the principles of emergent literacy, in which exposure to meaningful language and symbolic representations supports early reading readiness (Whitehurst & Lonigan, 1998; Herman et al., 2025).

Media expert validation also confirmed that the visual and animated elements of the e-comic were engaging, although some minor revisions were necessary (e.g., animation refinement and more relatable examples). Despite a slightly lower average score (82%), feedback led to useful modifications, resulting in a more polished version that maintained educational integrity while improving visual appeal.

3. Student Engagement and Learning Impact

The core objective of the study was to enhance children's ability to distinguish letters *b*, *d*, and *p*—was achieved, as evidenced in both limited and operational field trials. In the limited trials, the children displayed an average positive response rate of 86.28%, which increased to 90.02% in the operational test. Children not only remained attentive during the video but were also able to retell the story, engage in discussions, and most importantly, correctly identify the target

letters afterward. These results demonstrate that the e-comic media was not only effective in delivering content but also in fostering an enjoyable and immersive learning experience.

These findings support the existing literature, which highlights the benefits of multimedia learning tools in early childhood education. According to Mayer's Cognitive Theory of Multimedia Learning (2001), when verbal and visual information are presented simultaneously, learning is significantly enhanced. The use of colorful visuals, story-based learning, and interactive media elements in the e-comic aligns with this theory, helping young learners to process and retain abstract letter concepts more effectively.

4. Practical Implications

The high ratings from teachers and the strong responses from students suggest that the e-comic media can be adopted as a supplementary tool in PAUD (early childhood education) settings. Teachers can use it to complement traditional literacy teaching methods and help children struggling with letter differentiation. Additionally, because the video incorporates both literacy and moral education (e.g., sharing and empathy), it serves as a multidimensional teaching aid.

6. Conclusion

This study concludes that e-comic media, when thoughtfully designed and developmentally aligned, is a highly effective tool for enhancing early childhood literacy and numeracy, particularly in helping children distinguish visually similar letters such as *b*, *d*, and *p*. The use of engaging storytelling, colorful animations, and interactive visual cues in the media created a meaningful learning experience that aligned with young children's cognitive and emotional development stages. Validation results from experts in early childhood education, language, and media design confirm that the content is not only pedagogically sound but also engaging and accessible to its target audience.

The results of field testing, both in limited and operational classroom settings, showed that children responded positively to the e-comic video. Observation data revealed high levels of attention, enthusiasm, and comprehension among students, with more than 90% of the participants in the operational test demonstrating the ability to distinguish the targeted letters. These findings indicate that media successfully bridges entertainment with educational value, allowing learners to acquire foundational literacy skills in an enjoyable and memorable way. Additionally, the presence of moral messages embedded in the story (e.g., sharing and kindness) supports the holistic development of character, alongside academic growth.

Furthermore, the e-comic media developed in this study have practical implications for educators and curriculum developers. It serves as an innovative alternative to traditional methods, particularly for visual and auditory learners in early childhood settings. The positive reception from teachers and the ability to customize the format for various learning contexts highlights its scalability and relevance. As digital media become increasingly central in education, tools such as e-comic videos can serve as effective models for integrating technology into early learning while preserving essential pedagogical principles.

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Authors contributions

N.P., R.W., and I.Y. were responsible for study design and revising. R.W., E.B., and D.S. were responsible for data collection. N.P., R.W. and A.C.D.S. drafted the manuscript. N.P., I.Y., and R.W. revised the manuscript and H.H., N.P., and R.W. proofread it. All authors read and approved the final manuscript.

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No additional data are available.

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