

## Design and development of mixed reality-based digital algebra book to enhance students' numeracy skill

Aryo Andri Nugroho<sup>1\*</sup>, Ida Dwijayanti<sup>1</sup>, Muhammad Prayito<sup>1</sup>, Muhammad Khair Noordin<sup>2</sup>, Kristof Fenyvesi<sup>3</sup>

<sup>1</sup>Universitas PGRI Semarang, Indonesia

<sup>2</sup>Universiti Teknologi Malaysia, Malaysia

<sup>3</sup>University of Jyväskylä, Finland

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### ABSTRACT

The rapid advancement of digital technology has significantly transformed the field of education, particularly through the development of digital books. These digital books become more engaging when they integrate the real-world environment into a virtual format, enabling interactive learning experiences. One such technology that facilitates this integration is Mixed Reality (MR), which combines real-world and digital objects into an interactive environment. The aim of this research is to design and validate a Mixed Reality-based digital algebra book that enhances students' numeracy literacy skills while supporting effective classroom learning. The study followed the Borg & Gall research and development framework, collecting data through expert validation and readability tests. Media experts evaluated aspects such as general design, learning presentation, language feasibility, and graphical representation, achieving an average validation score of 89.2% from five validators. Material experts assessed the content substance, learning effectiveness, and overall usefulness, resulting in an average score of 92.6% from five validators. Readability tests conducted with teachers and lecturers yielded an average score of 86%, while tests conducted with students scored an average of 80%. Based on these results, the Mixed Reality-based digital algebra book was deemed valid and feasible for classroom use. Its implementation is expected to simplify the learning process, making classroom instruction more interactive and engaging while improving students' academic performance.

## INTRODUCTION

The rapid development of digital technology has created new opportunities for the education sector by facilitating its integration into the teaching and learning process (Razak, 2022). While digital learning is already well-known, its adoption in education continues to grow and expand globally (Amin & Sundari, 2020; Islam Sarker, 2019). This trend underscores the critical role of digital learning in enhancing the educational experience for both teachers and students.

In Indonesia, the digital transformation of education has posed significant challenges, particularly with the adoption of modern digital learning technologies and tools following the COVID-19 pandemic (Kovalenko, 2022). Educational practices incorporating digital resources are increasingly being developed across all educational levels, though implementation remains uneven (Cabero, 2022). Despite these advances, educational innovation still faces several challenges, including technological development, resource availability, pedagogical adjustments, and—most importantly—teacher preparedness to adopt new teaching methods (Lavicza, 2022). Recognizing

\*Corresponding author: [aryoandri@upgris.ac.id](mailto:aryoandri@upgris.ac.id)

these challenges, Indonesia's Ministry of Education and Culture launched the School Digitalization Program to provide technological tools and professional training for teachers and students across various regions (Kemendikbud, 2022).

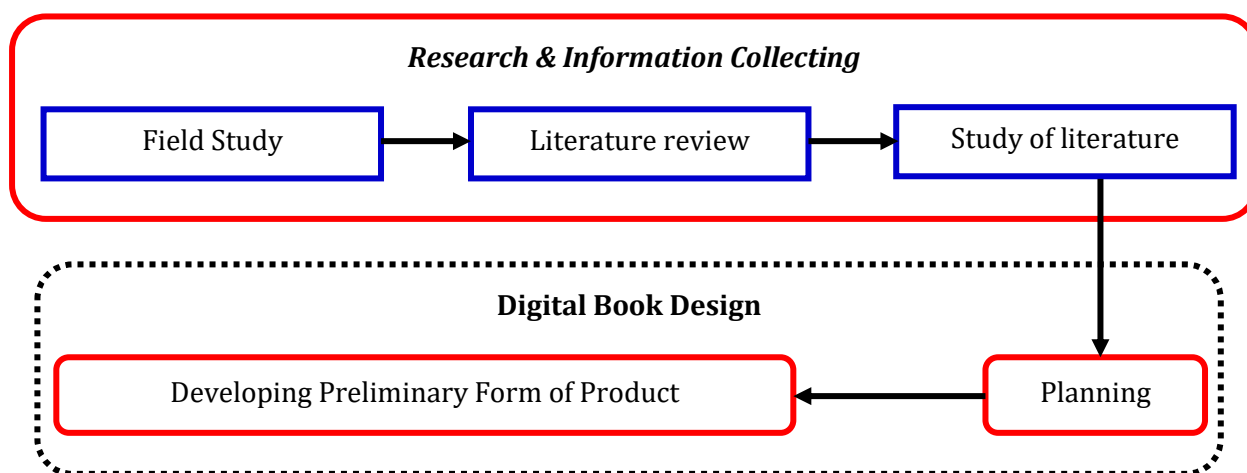
Twenty-first-century skills encompass the ability to create, use, critically evaluate, and contextualize information from various sources. Integrating real-world contexts into a virtual learning environment requires advanced technologies that can simulate real-world scenarios (Maas, 2020). In today's digital era, books have evolved from traditional printed formats to digital forms, offering greater practicality and convenience. Digital books, being portable and easily accessible, enable readers to study anytime and anywhere without needing to navigate entire texts manually (Nurhayati, 2017; Awang, 2010). Digital books serve as interactive learning media that provide virtual experiences (José, 2016). Research by Park et al. (2019) highlights how adopting digital books can increase student motivation and engagement. Consequently, teachers often integrate digital books into their lessons to create a dynamic and conducive learning environment (Lovenburg, 2018). Moreover, Hull and Chaparro (2006) demonstrated that digital books could offer interactive three-dimensional content, enhancing user engagement and comprehension. In alignment with these developments, the Indonesian National Core Curriculum has begun incorporating digital technology to make learning more relevant and adaptable to technological advancements (Kemendikbud, 2024).

Digital books become more engaging when they integrate real-world environments into virtual spaces, enabling users to interact through a seamless blend of physical and digital elements. A key technology that supports this integration is Mixed Reality (MR), which presents digital objects within the real world while allowing users to interact with them through touch and gestures. Although MR is emerging as a promising educational tool, its application in schools remains limited (Gatullo, 2022). Mixed Reality plays an increasingly important role in education by promoting active participation and knowledge development within a safe and engaging learning environment (Ogunseiju, 2022). It merges the real and virtual worlds, providing contextual learning experiences that allow students to explore realistic environments enriched with virtual interactions (Kaplan, 2021; Holz, 2011). Research has demonstrated that MR enhances material comprehension, language learning, and motivation for academic performance (Bacca, 2014; Lindgren & Johnson Glenberg, 2013; Radu, 2014). As a fusion of Augmented Reality (AR) and Virtual Reality (VR), MR combines the contextual benefits of AR, which supports visual learning by overlaying information on real-world objects, with the immersive experience of VR, which simulates real-life environments (Cabero, 2020; Ali, 2018). This unique combination makes MR an effective tool for fostering deeper understanding and engagement in educational settings.

The integration of technology in learning is essential for fostering students' literacy and numeracy skills (Fatahillah, 2020). Establishing a strong literacy and numeracy environment from an early age significantly influences children's mastery of reading, counting, and mathematical reasoning (Manolitsis, 2013). Numeracy literacy refers to the ability to understand and use numbers, symbols, and basic mathematical concepts to solve real-life problems, analyze data, interpret information, and make informed decisions (Culture, 2017). Although numeracy is often equated with mathematics, many students find mathematics challenging due to its abstract nature (Agustina & Martha Rusmana, 2019). Ekowati et al. (2019) describe numeracy literacy as the ability to apply logical reasoning in mathematical contexts. To enhance this skill, learning media must go beyond traditional audio-visual methods. Engaging, interactive tools can make learning enjoyable and reduce boredom (Putri, 2022).

One promising tool for developing numeracy literacy is a Mixed Reality (MR)-enhanced digital book, which merges real and virtual environments by combining Augmented Reality (AR) and Virtual Reality (VR). This hybrid approach offers an immersive and interactive learning experience that helps students visualize mathematical concepts more clearly.

Discussions with the Semarang City Subject Teacher Conference highlighted that Class VII algebra materials require concrete contextualization due to their abstract nature. Existing teaching materials lack real-world visualization, creating a gap in students' understanding. Therefore, this study aims to design and develop a Mixed Reality-Based Digital Book for Class VII Algebra, test its validity, and evaluate its readability to improve students' numeracy literacy skills.



**Figure 1.** Development process for a mixed reality-based digital algebra book

## METHODS

This study followed the research and development (R&D) model established by Borg and Gall, as described by Sugiyono (2016). The model outlines ten systematic development steps: (1) Research and Information Collection, (2) Planning, (3) Developing a Preliminary Product, (4) Conducting Preliminary Field Testing, (5) Revising the Main Product, (6) Conducting Main Field Testing, (7) Revising the Operational Product, (8) Conducting Operational Field Testing, (9) Final Product Revision, and (10) Dissemination. For the purpose of this research, the focus was limited to the third step, Developing the Preliminary Product, specifically through expert validation and readability testing.

The development process began with the Research & Information Collection stage, which included field studies and literature reviews. During the field study, researchers identified key challenges and gathered data necessary for designing a mixed reality-based digital algebra book. The literature review involved examining prior research findings as references for potential solutions and exploring relevant theories and concepts related to the research problem. The Planning stage involved setting clear research objectives, defining goals for each development phase, and determining the expertise required to address identified challenges effectively. The Preliminary Product Development stage included designing the first draft of the mixed reality-based digital algebra book (Draft 1), conducting expert validation, and revising the draft based on the feedback received. This iterative process ensured the product met both educational and technical standards. The overall development process is illustrated in Figure 1.

The data collection procedure for this study involved expert validation of the mixed reality-based digital algebra book design. The validation process was conducted using the expert judgment method combined with focus group discussions (FGD). The validation panel consisted of five mathematics teachers and two mathematics education lecturers, ensuring a diverse range of expertise. To gather validation data, researchers used customized validation sheets, readability assessment forms, and discussion note sheets designed specifically to evaluate the functionality, content accuracy, and usability of the digital book. This comprehensive approach ensured that both educational content and technological aspects of the digital book met the required standards.

## FINDINGS

In this study, a mixed reality-based digital algebra book was developed following the Borg and Gall model of development research, with each stage carefully adapted to align with the study's specific objectives.

### Research and information collecting

This stage involved both field studies and literature reviews. During the field study, researchers identified challenges and gathered data related to the design of a mixed reality-based

digital algebra book. The analysis of existing teaching materials used by junior high school mathematics teachers, particularly in Grade 7, revealed several shortcomings:

1. Limited and Inaccurate Illustrations: Existing algebraic materials contained minimal and imprecise visual representations that failed to reflect real-world contexts familiar to students.
2. Text-Heavy Content: The materials were predominantly text-based, limiting students' engagement and comprehension.
3. Lack of Constructive Learning Activities: The teaching materials did not sufficiently promote active, student-centered learning practices.
4. Insufficient Character Development Support: Current resources lacked components that fostered character-building in students.
5. Absence of 3D Visualizations: The materials did not incorporate three-dimensional illustrations to enhance conceptual understanding.
6. Inadequate Teacher Guidelines: There were no clear instructional guides to assist teachers in conducting follow-up activities after students explored the materials.
7. Scarcity of Digital Resources: Few digital books on algebraic concepts were available, limiting the adoption of interactive learning technologies

The literature review explored previous studies on mixed reality and numeracy literacy in learning. It examined theories and concepts related to the development of digital algebra books based on mixed reality, referencing both national and international academic journals. These insights informed the development process and provided foundational knowledge for addressing the identified educational gaps.

### Planning

This stage involves defining research objectives, establishing specific goals for each stage of the research process, and identifying the necessary expertise required to address the research challenges effectively. The primary aim of this study is to design and develop a mixed reality-based digital algebra book aimed at enhancing students' numeracy literacy by providing interactive, contextually relevant learning experiences.

### Developing preliminary form of product

The field study results revealed several limitations in the teaching materials used by junior high school mathematics teachers in Semarang City. To address these shortcomings, several key development priorities were established:

1. Contextual Learning Environment: The learning environment should reflect real-life contexts, enabling students to connect their experiences to specific mathematical concepts.
2. Curriculum Alignment: The environment must align with the independent curriculum framework for junior high schools.
3. Familiar Contexts: The presented learning scenarios should be recognizable and relatable to students' daily lives.
4. Interactive Learning Activities: The materials should include hands-on activities that actively engage students.
5. Skill Integration: In addition to mathematical content, the teaching materials should incorporate literacy and numeracy skill development.

Based on these development priorities, the prototype teaching materials were designed and outlined in Table 1. Following this, an initial draft of the mixed reality-based digital algebra book was developed to improve students' numeracy literacy skills. Figure 2 to Figure 6 provide a visual overview of the digital book's structure and content

At the preliminary product development stage, both validity and readability tests were conducted to ensure the feasibility of the mixed reality-based algebra digital book. The product validity test evaluated the digital book's quality based on assessments by subject-matter experts, including mathematics teachers and lecturers. The results of the expert evaluations from material validators are summarized in Table 2, while evaluations from media validators are presented in Table 3.

The validation results from media experts presented in [Table 2](#) and [Table 3](#) indicate that the mixed reality-based algebra digital book designed to enhance students' numeracy literacy skills achieved average scores of 4.63 and 4.62, respectively. These scores demonstrate that the developed digital book meets the criteria for high-quality and valid teaching materials.

Additionally, a readability test was conducted with mathematics teachers, lecturers, and students from several schools, including SMPN 23 Semarang, SMPN 3 Semarang, SMPN 36 Semarang, SMPN 33 Semarang, and SMPN 42 Semarang. The results of the readability test for teachers and lecturers are summarized in [Table 4](#), while students' readability evaluations are detailed in [Table 5](#). The average readability scores from teachers and lecturers reached 4.3, while students' ratings averaged 4.0, indicating that the digital book is clear, comprehensible, and suitable for classroom use. These findings affirm that the digital book is both valid and practically applicable for enhancing students' learning experiences.



Figure 2. Front cover

## E. Tahukah Kamu

Siapaakah Bapak Aljabar?  
Simak tayangan video berikut untuk mengenal bapak aljabar kita!



QR Bapak Aljabar

Bapak Aljabar dilahirkan di BUKHARA dan hidup di Khawarizm, Usbekistan pada tahun 194H/780M dan meninggal pada tahun 266H/850 M di Baghdad.

Figure 3. Father of Algebra

## A Unsur-Unsur Bentuk Aljabar

RESTORAN SEA FOOD



Pak Dendi mempunyai usaha restoran sea food. Untuk memenuhi kebutuhan restoran, setiap hari Pak Dendi membeli ikan laut di tempat pelelangan ikan. Kualitas ikan yang dibeli Pak Dendi selalu segar. Setiap membeli ikan, pak Dendi selalu membawa 6 kotak styrofoam ikan dengan berat ikan selalu sama dalam setiap kotak tersebut.

Pada akhir pekan, pengunjung restoran sea food Pak Dendi selalu ramai dan ikan yang disediakan harus ditambah. Pak Dendi sudah mempunyai tempat langganan membeli ikan, yaitu di tempat Pak Indra. Komunikasi yang dilakukan oleh Pak Dendi dan Pak Indra ketika terjadi transaksi adalah sebagai berikut:

## B Operasi Aljabar dan Sifatnya

1. Penjumlahan dan Pengurangan  
BELANJA DI TOKO



Intan, Yuni dan Rina mendapatkan pesanan tetangga untuk membeli telur dan sosis. Mereka bertiga sepakat untuk membeli barang tersebut di toko "Anugerah" milik Ibu Dinda. Setelah dihitung, telur yang dibeli sebanyak 5 keranjang telur dan sosis 2 pak sosis.

Figure 4. Elements of Algebraic Forms

Figure 5. Algebraic Operations and Their Properties

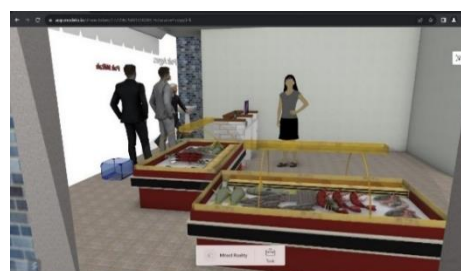


Figure 6. Example of Mixed Reality

**Table 1**  
Mixed reality based digital book prototype

| Material                                        | Content of the Problem                       | Mixed Reality                                                                                                                                        | Literacy                                                                                                                                                            | Numeracy                                                                                                                    |
|-------------------------------------------------|----------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|
| Introduction to Algebra                         | Crab Farming                                 | Virtual reality about the crab farming environment along with crab sightings using augmented reality                                                 | It shows that crabs can be processed into mixed products such as spring rolls and crab meatballs,                                                                   | - Demonstrate the potential of crab farming to have marketable value<br>- Modelling crab farming problems in algebraic form |
| Getting to know Algebraic Forms                 | Disaster Care                                | Virtual reality about the disaster environment along with the appearance of clothes in a cardboard box using augmented reality                       | Collecting used clothes into boxes to provide assistance to disaster victims                                                                                        | Write in one sentence or in the form of symbols to determine the number of all used clothes collected                       |
| Learners' Activity in Knowing Algebraic Forms   | Purchase of Eggs for Making Bread            | Virtual reality about the environment of a supermarket or grocery store along with the appearance of buying and selling eggs using augmented reality | Demonstrate the process of buying and selling eggs at a supermarket or grocery store as ingredients for bread.                                                      | Determine the number of eggs used to make bread                                                                             |
| Elements of Algebraic Forms                     | Sea Food Restaurant                          | Virtual reality about the environment of sea food restaurants along with the appearance of fish in Styrofoam using augmented reality.                | Shows the process of buying fish in each Styrofoam required by the owner of the sea food restaurant, Mr Dendi, with the sea food restaurant's fish seller, Mr Indra | Determining the weight of each Styrofoam box filled with fish                                                               |
| Learner Activity in Elements of Algebraic Forms | Counting packet books on the library shelves | Virtual reality about the Library environment along with the appearance of books on the shelves using augmented reality                              | Showing package books at each level of the bookshelf in the library                                                                                                 | Counting the number of all books on each shelf level in the library                                                         |
| Algebraic Operations and their properties       |                                              |                                                                                                                                                      |                                                                                                                                                                     |                                                                                                                             |
| 1. Addition and Subtraction                     | 1. Shop at the Store                         | 1. Virtual reality about the Shop environment along with the appearance of eggs in baskets using augmented reality.                                  | 1. Shows the process of buying and selling eggs and sausages in a shop.                                                                                             | 1. The number of eggs and sausages bought by Yuni and Rina                                                                  |
| 2. Multiplication and Division                  | 2. Package delivery                          | 2. Virtual reality about the environment of the rice warehouse along with the appearance of rice using augmented reality                             | 2. A person delivering a package of rice using a three-wheeled vehicle                                                                                              | 2. Determine the weight of the rice delivered by the delivery man                                                           |

**Table 1 (Continued)**

| Material                                                      | Content of the Problem                 | Mixed Reality                                                                                                                                                     | Literacy                                                                                                                                                                                                            | Numeracy                                                   |
|---------------------------------------------------------------|----------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------|
| Learner Activity in Algebraic Operations and Their Properties | Smartphone buying and selling business | Virtual reality about the environment of smartphone buying and selling stores along with the appearance of smartphones in the marketplace using augmented reality | Smartphone buying and selling shop owners try to fulfill their goods by importing from the marketplace                                                                                                              | Counting the number of boxes imported from the marketplace |
| Factoring Algebraic Forms                                     | Ideal Home                             | Virtual reality about the ideal home environment along with the appearance of the interior and exterior design of the house using augmented reality               | The ideal home is a comfortable home for shelter from the outside weather and a place for family to gather. A comfortable home can be seen from the interior and exterior design, including the spatial arrangement | Area of house size to be occupied with known land size     |

**Table 2**

## Material expert validation results

| Aspects                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Average score |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| <b>General Aspects</b><br>This mathematics digital book media aligns with the current curriculum, featuring an engaging, concise, and clear design. It is practical and beneficial for all learners receiving the material, representing a new innovation in educational media that enhances the learning experience.                                                                                                                                                                                            | 4.8           |
| <b>Aspects of Material Substance</b><br>This digital book media aligns with mathematics learning objectives, using terminology appropriate for the students' academic level. The topics are clearly presented, and the content is organized systematically, ensuring a coherent and effective learning experience.                                                                                                                                                                                               | 4.65          |
| <b>Learning Aspects</b><br>This aspect highlights how the use of digital book media facilitates the learning process by simplifying material delivery for teachers and ensuring that the content aligns with specified learning objectives. It supports independent learning by providing examples and practice questions tailored to stimulate students' literacy and numeracy skills. Through interactive tasks and relevant exercises, students can better understand and engage with the material presented. | 4.57          |
| <b>Expediency Aspect</b><br>This digital book media can be used as an alternative to learning, is able to help make it easier for students to learn math, provides an interesting learning nuance to eliminate boredom in learning math, can facilitate students to learn independently, can be reused or to develop other learning media.                                                                                                                                                                       | 4.52          |
| Average                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | 4.63          |

**Table 3**  
Media expert validation results

| Aspects                                                                                                                                                                                                                                                                                                | Average score |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| <b>General Aspects</b><br>This math digital book media is an interesting media development, designed in an attractive and easy to understand way, can improve literacy and numeracy of students, can have advantages over conventional media.                                                          | 4.65          |
| <b>Learning Presentation Aspect</b><br>The front title (cover) already uses the material to be learned, The use of digital book media is easy to understand, This digital book media contains sample questions, The systematic presentation of learning in digital book media is presented coherently. | 4.7           |
| <b>Aspects of Language Feasibility</b><br>The use of language in this digital book media is in accordance with the intellectual development of students, in accordance with the emotional level of students, easy for students to understand.                                                          | 4.46          |
| <b>Aspects of Graphic Feasibility</b><br>The appearance of this digital book media is attractive, according to the field of mathematics, does not use too many combinations of types and letters, colors, elements, harmonious layout and clarify its function.                                        | 4.7           |
| Average                                                                                                                                                                                                                                                                                                | 4.62          |

**Tabel 4**  
Teacher and lecturer readability test results

| Aspects                                                                                      | Average Score |
|----------------------------------------------------------------------------------------------|---------------|
| The material presented in each subchapter is clear and easy to understand                    | 4.6           |
| The sentences used are clear and easy to understand                                          | 4.4           |
| The language used is easy to understand                                                      | 4.6           |
| The content component of the digital book is presented in an attractive manner               | 4.4           |
| The instructions on this digital book are clear and easy to understand                       | 4.4           |
| The phenomena or examples presented in this digital book can be found in everyday life.      | 3.8           |
| Practice questions in accordance with the material contained in the digital book             | 4.2           |
| Images in the digital book can help understand the material                                  | 5             |
| The animation or video is clear and helps in understanding the material.                     | 4.8           |
| In each chapter there is a virtual reality that illustrates the problems discussed.          | 4             |
| The initial display describes the overall material that will be studied in the digital book. | 3.8           |
| The display in the module is attractive and harmonises with the front display                | 4.2           |
| The font used is easy to read and does not have too many variations                          | 4.4           |
| This digital book is interesting and not boring for learning                                 | 3.8           |
| This digital book makes it easier to understand the material learnt                          | 4             |
| Average                                                                                      | 4.3           |

**Tabel 5**  
Learner Readability Test Results

| Aspects                                                                                      | Average Score |
|----------------------------------------------------------------------------------------------|---------------|
| The material presented in each subchapter is clear and easy to understand                    | 4,08          |
| The sentences used are clear and easy to understand                                          | 3.97          |
| The language used is easy to understand                                                      | 4.14          |
| The content component of the digital book is presented in an attractive manner               | 3.97          |
| The instructions on this digital book are clear and easy to understand                       | 4.16          |
| The phenomena or examples presented in this digital book can be found in everyday life.      | 3.95          |
| Practice questions in accordance with the material contained in the digital book             | 3.92          |
| Images in the digital book can help understand the material                                  | 4.08          |
| The animation or video is clear and helps in understanding the material.                     | 4.03          |
| In each chapter there is a virtual reality that illustrates the problems discussed.          | 3.81          |
| The initial display describes the overall material that will be studied in the digital book. | 3.92          |
| The display in the module is attractive and harmonises with the front display                | 4.16          |
| The font used is easy to read and does not have too many variations                          | 4.11          |
| This digital book is interesting and not boring for learning                                 | 3.86          |
| This digital book makes it easier to understand the material learnt                          | 4.08          |
| Average                                                                                      | 4             |

## DISCUSSION

Based on the results of problem identification and data collection, it became evident that existing teaching materials for algebra lack technological integration that facilitates easier student learning. Current materials neither represent real-world objects nor relate to students' daily lives. To address this gap, this research developed teaching materials using E-modules packaged as digital books, which can be accessed via laptops and mobile phones, ensuring availability anytime and anywhere (Li, 2011). According to Ran (2020), digital books provide learners with greater flexibility and play a crucial role in constructing learning resources. Fang (2011) also highlights that digital books digitize traditional printed materials into accessible digital files, viewable on various devices such as mobile phones and computers. Integrating technology into learning must align with literacy and numeracy development, making the educational experience more meaningful. The use of digital books during the learning process has been found to enhance students' higher-order thinking and literacy skills (Siregar, 2021). while also fostering reading literacy (Febriana & Nugroho, 2023). The OECD (2020) defines literacy and numeracy as the ability of learners to formulate, apply, and interpret mathematics in various real-life contexts, which are critical skills supporting academic achievement and lifelong learning (Echaves, 2024). To bridge the gap between real-world environments and digital learning, Mixed Reality (MR) emerges as a promising technology. MR combines elements of virtual reality (VR), augmented reality (AR), and the real world to create immersive learning experiences (Carre et al., 2022). This technology blends real and virtual worlds to contextualize user perception, enhancing the learning process (Leonard and Fitzgerald, 2018). In the educational field, MR has demonstrated significant potential by facilitating better understanding through the integration of realistic and interactive learning environments (Kerdvibulvech, 2022; Marin and Vega, 2022). Guided by these insights, researchers designed a Mixed Reality-based digital book for algebra instruction, with a particular emphasis on improving literacy and numeracy skills. This digital book visualizes algebraic concepts in real-life contexts through a customized virtual environment, making learning more engaging and accessible to students.

The validation results confirmed that the mixed reality-based algebra digital book designed to enhance students' literacy and numeracy skills met the required validity criteria. Validators emphasized that the digital book is engaging, easy to understand, and effective in fostering critical thinking. The presentation style aligns well with the developmental characteristics of grade 7

students, incorporating numeracy literacy activities and recognizing various emotional and character aspects. As noted by Ernia and Mahmudah (2023), digital books can effectively train students' numeracy literacy. Validators also highlighted that this digital book simplifies lesson planning and instructional delivery for teachers, supporting improved teaching practices. According to Sandy et al. (2022), using digital books in teaching can enhance students' mathematical communication skills while assisting teachers in delivering content effectively. The validators also noted that the book's content is logically structured, with clearly presented topics and terminology appropriate for the students' knowledge levels. This digital book aligns well with introducing and reinforcing numeracy literacy (Hamiedah et al., 2023). Its innovative and interactive features make it an effective tool for classroom learning, enhancing both student engagement and performance (Nugroho & Purwati, 2015). Additionally, the interactive design enables students to learn independently and strengthens their problem-solving abilities (Utami et al., 2018).

The readability test results involving teachers, lecturers, and students confirmed that the digital book is feasible and easy to use. The content, language, and instructions are clear and easy to follow, while the cover design and internal layout are visually appealing. The real-life examples, practice exercises, and animated illustrations in the digital book help simplify complex concepts. Each chapter includes virtual reality-enhanced content illustrating key problems, which improves understanding. As Devetak and Vogrinc (2013) argue, the effectiveness of teaching materials depends on the quality of their language, as text forms the foundation of educational content. Factors such as text structure, vocabulary difficulty, coherence, and syntax play significant roles in determining readability (Maulita, 2023).

Overall, the mixed reality-based digital book has proven to be an accessible and effective learning tool, enabling students to learn independently and gain a better understanding of algebra through contextualized, interactive content. Additionally, its design incorporates feedback from the Semarang City Subject Teacher Conference (FGD) to ensure alignment with the grade 7 algebra curriculum, further supporting its practical application in real educational settings

## CONCLUSION

This study developed a mixed reality-based algebra digital book following the Borg and Gall model. The validation and readability test results confirmed that the digital book is valid, suitable for use, and effectively supports the improvement of students' literacy and numeracy skills in algebra. Feedback from validators was carefully considered and integrated into the final design, enhancing the quality and usability of the digital book.

The digital book creates an immersive learning environment closely related to students' real-world experiences through mixed reality technology, making abstract algebraic concepts more accessible and engaging. Its design aligns with the specific learning needs of both teachers and students, offering a practical and interactive learning tool.

This research, however, is limited to the validation and readability test phases. Future studies should extend the work to the implementation stage, evaluating its impact on learning outcomes in classroom settings and exploring its potential for broader educational applications.

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## AUTHOR'S DECLARATION

### Authors' contributions

All authors contributed to the concept and design of the study as well as result of its. The AAN: initiator of the main idea and concept of the study, ID: data analysis and validation, MP: data collection and reporting, MKN: Review and Editing, KF: Review and Editing.

|                                           |                                                                                                                                                                                                           |
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## BIBLIOGRAPHY

- Agustina, L., & Martha Rusmana, I. (2019). Pembelajaran Matematika Menyenangkan Dengan Aplikasi Kuis Online Quizizz. *AL-IDARAH Jurnal Kependidikan Islam*, 9,1-7
- Ali, D. F., Omar, M., Boon, Y., Ahmad, J., Wahid, N. H. A., Noordin, M. K., ... & Ibrahim, M. A. (2018). The use of augmented reality learning environment in enhancing students' mental rotation skills. *Advanced Science Letters*, 24(5), 3705-3708. <https://doi.org/10.1166/asl.2018.11470>
- Amin, F. M., & Sundari, H. (2020). Efl students' preferences on digital platforms during emergency remote teaching: Video conference, lms, or messenger application?. *Studies in English Language and Education*, 7(2), 362-378. <https://doi.org/10.24815/siele.v7i2.16929>
- Awang, N. H. (2010). BUKU VS E-BUKU: TRANSFORMASI ERA DIGITAL. *Jurnal PPM*, 5, 1-14.
- Bacca, J., Baldiris, S., Fabregat, R., Graf, S., & Kinshuk (2014). Augmented reality trends in education: A systematic review of research and applications. *Journal of Educational Technology & Society*, 17(4), 133-149.
- Cabero-Almenara, J.; Vázquez-Cano, E.; López-Meneses, E.; Jaén, A. Posibilidades formativas de la tecnología aumentada. Un estudio diacrónico en escenarios universitarios. *Rev. Complut. Educ.* 2020, 31, 143-154. <https://doi.org/10.5209/ced.61934>
- Cabero-Almenara, J., Llorente-Cejudo, C., & Martinez-Roig, R. (2022). The use of mixed, augmented and virtual reality in history of art teaching: A case study. *Applied System Innovation*, 5(3), 44. <https://doi.org/10.3390/asi5030044>
- Carre, A.L., Dubois, A., Partarakis, N., Zabulis, X., Patsiouras, N., Mantinaki, E., Zidianakis, E., Cadi, N., Baka, E., Thalmann, N.M., Makrygiannis, D., Glushkova, A. and Manitsaris, S. (2022), "Mixed-reality demonstration and training of glassblowing", *Heritage*, Vol. 5 No. 1, pp. 103-128, <https://doi.org/10.3390/heritage5010006>.
- Devetak, I., & Vogrinc, J. (2013). The Criteria for Evaluating the Quality of the Science Textbooks. *In Critical Analysis of Science Textbooks*. [https://doi.org/10.1007/978-94-0074168-3\\_1](https://doi.org/10.1007/978-94-0074168-3_1)
- Echavez Jr, A., Yncierto, C., Obiasada, R., Dayag, M., Alcazar, R., & Kilag, O. K. (2024). Advancing Literacy and Numeracy: Exploring Trends and Strategies for Elementary School Students. *International Multidisciplinary Journal of Research for Innovation, Sustainability, and Excellence (IMJRIS)*, 1(2), 144-150.
- Ekowati, D. W., Astuti, Y. P., Utami, I. W. P., Mukhlisina, I., & Suwandayani, B. I. (2019). Literasi Numerasi di SD Muhammadiyah. *ELSE (Elementary School Education Journal): Jurnal Pendidikan Dan Pembelajaran Sekolah Dasar*, 3(1), 93. <https://doi.org/10.30651/else.v3i1.2541>
- Fang, H.G., Liu, P. and Huang, R.H. (2011). "The Research on E-book-oriented Mobile Learning System Environment Application and Its Tendency". *Modern Educational Technology*, (12):18-23.
- Fatahillah, A., Puspitasari, I. D., & Hussien, S. (2020). The Development of Schoology Web-Based Learning Media with GeoGebra to Improve the ICT Literacy on Quadratic Functions. *Journal of Research and Advances in Mathematics Education*, 5(3), 304-316. <https://doi.org/10.23917/jramathedu.v5i3.10692>
- Febriana, A., & Nugroho, A. A. (2023). Pengembangan digital book Berbasis Asesmen Kompetensi Minimum (AKM) untuk meningkatkan literasi membaca peserta didik. *Pendas: Jurnal Ilmiah Pendidikan Dasar*, 8(1), 524-538.
- Gattullo, M., Laviola, E., Boccaccio, A., Evangelista, A., Fiorentino, M., Manghisi, V. M., & Uva, A. E. (2022). Design of a mixed reality application for STEM distance education laboratories. *Computers*, 11(4), 50. <https://doi.org/10.3390/computers11040050>
- Hamiedah, D., Fauziyah, N., & Huda, S. (2023). Pengembangan E-modul Menggunakan Aplikasi Ispring Suite 10 dengan Penguatan Literasi Numerasi pada Peserta Didik SMP. *DIDAKTIKA: Jurnal Pemikiran Pendidikan*, 29(1), 73. <https://doi.org/10.30587/didaktika.v29i1.5176>
- Holz, T., Campbell, A. G., O'Hare, G. M. P., Stafford, J. W., Martin, A., & Dragone, M. (2011). MiRA – Mixed reality agents. *International Journal of Human-Computer Studies*, 69(4), 251-268. <https://doi.org/10.1016/j.ijhcs.2010.10.1>

- Hull, S. S., & Chaparro, B. S. (2006). Usability Evaluation of Digital Flipviewer® Online Flipbooks. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, 50(17), 1839-1843. <https://doi.org/10.1177/154193120605001726>
- Islam Sarker, M. N., Wu, M., Cao, Q., Alam, G. M. M., & Li, D. (2019). Leveraging Digital Technology for Better Learning and Education: A Systematic Literature Review. *International Journal of Information and Education Technology*, 9(7), 453-461. <https://doi.org/10.18178/ijiet.2019.9.7.1246>
- José Antonio Cordón-García, Daniel Linder, R. G.-D. and J. A.-A. (2016). E-Book publishing in Spain The paradoxes of a dual model. *Journal of Enterprise Information Management*, 29(1), 118-139.
- Kaplan, A. D., Cruick, J., Endsley, M., Beers, S. M., Sawyer, B. D., & Hancock, P. A. (2021). The effects of virtual reality, augmented reality, and mixed reality as training enhancement methods: A meta-analysis. *Human factors*, 63(4), 706-726. <https://doi.org/10.1177/0018720820904229>
- Kementerian Pendidikan dan Kebudayaan. (2017). *Gerakan Literasi Nasional*. Jakarta: Kementerian Pendidikan dan Kebudayaan. <https://repository.kemdikbud.go.id/11628/1/materi-pendukung-literasi-numerasi-rev.pdf>.
- Kementerian Pendidikan dan Kebudayaan. (2022). *Laporan tahunan digitalisasi sekolah 2022*. Jakarta: Kementerian Pendidikan dan Kebudayaan. <https://www.kemdikbud.go.id/main/blog/2022/02/laporan-tahunan-digitalisasi-sekolah-2022>
- Kementerian Pendidikan dan Kebudayaan. (2024). *Laporan tahunan Program Merdeka Belajar 2024*. Jakarta: Kementerian Pendidikan dan Kebudayaan. <https://www.kemdikbud.go.id/main/blog/2024/03/laporan-tahunan-program-merdeka-belajar-2024>
- Kerdvibulvech, C. (2022), "Geo-Based mixed reality gaming market analysis", *Human Behavior and Emerging Technologies*, pp. 1-9, <https://doi.org/10.1155/2022/1139475>
- Kovalenko, V., Marienko, M., & Sukhikh, A. (2022). Use of augmented and virtual reality tools in a general secondary education institution in the context of blended learning. *arXiv preprint arXiv:2201.07003*.
- Lavicza, Z., Weinhandl, R., Prodromou, T., Andić, B., Lieban, D., Hohenwarter, M., ... & Diego-Mantecón, J. M. (2022). Developing and evaluating educational innovations for STEAM education in rapidly changing digital technology environments. *Sustainability*, 14(12), 7237. <https://doi.org/10.3390/su14127237>
- Leonard, S.N. and Fitzgerald, R.N. (2018), "Holographic learning: a mixed reality trial of Microsoft HoloLens in an Australian secondary school", *Research in Learning Technology*, Vol. 26, <https://doi.org/25304/rlt.v26.2160>
- Lindgren, R., & Johnson-Glenberg, M. (2013). Emboldened by embodiment: Six precepts for research on embodied learning and mixed reality. *Educational Researcher*, 42(8), 445-452. <https://doi.org/10.3102/13189X13511661>
- Li, L., Wang, D., Qin, W.S., Zhang S.Q. and Gao, X. (2011). "On the Inevitability of the Development Trend of Electronic Teaching Materials Replacing Paper Teaching Materials". *China Information Times*, (5):42-44.
- Lovenburg, N. (2018). Journey within Afghanistan: Inside creative's digital book tracking system. *Childhood Education*, 94(5), 52-57. <https://doi.org/10.1080/00094056.2018.1516473>
- Maas, M. J., & Hughes, J. M. (2020). Virtual, augmented and mixed reality in K-12 education: A review of the literature. *Technology, Pedagogy and Education*, 29(2), 231-249. <https://doi.org/10.1080/1475939X.2020.1737210>
- Manolitsis, G., Georgiou, G. K., & Tziraki, N. (2013). Examining the effects of home literacy and numeracy environment on early reading and math acquisition. *Early Childhood Research Quarterly*, 28(4), 692-703.
- Marín, V. and Vega, E. (2022), "La formación del docente de enseñanza secundaria en torno a la realidad mixta en ámbitos inclusivos", in Sánchez-Rivas, E., Colomo-Magana, E., Ruiz-Palmero, J. and Gómez-García, M. (Eds), *La tecnología educativa como eje vertebrador de la innovación*, Octaedro, Barcelona, pp. 73-85.
- Maulita, I. (2023). Analisis Kelayakan Bahan Ajar Berbasis Literasi Sains Pada Tema Gaya. *Perwira Journal of Economics & Business*, 3(01), 84-90.
- Nugroho, A. A., & Purwati, H. (2015). Pengembangan Media Pembelajaran Matematika Berbasis Mobile Learning Dengan Pendekatan Scientific. *Euclid*, 2(1). <https://doi.org/10.33603/e.v2i1.355>
- Nurhayati, D. (2017). Developing Interactive Digital Book for The Development of E-Learning Course on Educational Technology Students of Faculty of Science Education, Yogyakarta State University. *E-Jurnal Prodi Teknologi Pendidikan*, VI(5), 458-473.
- OECD. (2020). *PISA 2018 Results (Volume VI): Are Students Ready to Thrive in an Interconnected World?*. Paris: OECD Publishing. <https://doi.org/10.1787/d5f68679-en>.
- Ogunseiju, O. R., Gonsalves, N., Akanmu, A. A., Bairaktarova, D., Bowman, D. A., & Jazizadeh, F. (2022). Mixed reality environment for learning sensing technology applications in Construction: A usability study. *Advanced Engineering Informatics*, 53, 101637. <https://doi.org/10.1016/j.aei.2022.101637>
- Park, B., Chang, H., & Park, S. (Steven). (2019). Adoption of digital devices for children education: Korean case.

- Telematics and Informatics*, 38(November), 247–256. <https://doi.org/10.1016/j.tele.2018.11.002>
- Putri, F. S. (2022). Aplikasi Multimedia dan Model Pembelajaran Blended Learning untuk Literasi Numerasi Peserta Didik Sekolah Dasar. *Jurnal Pendidikan*, 22(2), 155–161. <https://doi.org/10.52850/jpn.v22i2.3918>
- Radu, I. (2014). Augmented reality in education: A meta-review and cross-media analysis. *Personal and Ubiquitous Computing*, 18(6), 1533–1543. <https://doi.org/10.1007/s00779-13-747-y>
- Ran, W., & Jinglu, L. (2020, October). The design and development of digital books for e-learning. In *2020 4th International Conference on Artificial Intelligence and Virtual Reality* (pp. 51-55). <https://doi.org/10.1145/3439133.3439140>
- Razak, A. N. A., Noordin, M. K., & Khanan, M. F. A. (2022). Digital learning in technical and vocational education and training (TVET) in public university, malaysia. *Journal of Technical Education and Training*, 14(3), 49-59. <https://doi.org/10.30880/jtet.2022.14.03.005>
- Siregar, B. H., Mansyur, A., & Siregar, N. (2021). Development of digital book in enhancing students' higher-order thinking skill. In *Journal of Physics: Conference Series* (Vol. 1819, No. 1, p. 012046). IOP Publishing. <https://doi.org/10.1088/1742-6596/1819/1/012046>
- Sugiyono. (2016). *Metode Penelitian Pendekatan Kuantitatif Kualitatif dan R&D*. Bandung: Alfabeta.
- Utami, R. E., Nugroho, A. A., Dwijayanti, I., & Sukarno, A. (2018). Pengembangan E-Modul Berbasis Etnomatematika Untuk Meningkatkan Kemampuan Pemecahan Masalah. *JNPM (Jurnal Nasional Pendidikan Matematika)*, 2(2), 268. <https://doi.org/10.33603/jnpm.v2i2.1458>