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# Bringing Space into the Classroom: An AR-Integrated E-Book on the Solar System for Students in Elementary School

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**Abstract:** This study aims to develop an Augmented Reality (AR)-integrated e-book on solar system material to support science education. The development process followed five stages: Analysis, Design, Development, Implementation, and Evaluation. The e-book was validated by experts, yielding a score of 93.36%, indicating it is highly feasible for use in educational settings. Student responses were also assessed, with a score of 88.23%, categorizing the e-book as "very good." Key features of the AR-integrated e-book include enhanced object visualization, allowing students to explore the solar system in greater detail, and interactive elements that encourage active participation in the learning process. These features help improve students' conceptual understanding and engagement with the material. The results suggest that the AR-integrated e-book is an effective educational tool, offering a modern approach to teaching solar system content. By incorporating AR technology, the e-book creates an immersive and engaging learning experience that enhances both comprehension and student involvement. The study concludes that this AR-based e-book is a valuable resource for science education, particularly for teaching complex subjects like the solar system, and has the potential to be applied effectively in various educational contexts.

**Keywords:** Augmented reality; Interactive e-book; Solar system

## Introduction

Science learning plays a strategic role in optimizing students' potential by not only presenting facts about nature but also fostering scientific thinking through observation, experimentation, and critical reasoning. In elementary education, science is crucial for developing curiosity, critical thinking, and problem-solving skills, which are essential for daily life. Harlen (2010) emphasizes that science education helps develop conceptual understanding, scientific process skills, and attitudes. It also equips students with methods for exploring natural phenomena, connecting knowledge to real-world applications through observation and experimentation (DeBoer, 2019). Science education prepares students to adapt to rapid advancements in science and technology, enhancing their analytical and problem-solving abilities (Jufrida et al., 2019). Moreover, Sutarto et al. (2021) highlight the importance of contextual and hands-on learning in science, which allows students to apply scientific concepts in their daily lives. To engage students and foster deeper exploration, creative and innovative teaching methods are necessary to make science both enjoyable and relevant (Rahman et al., 2025; Sihombing et al., 2025).

Science learning plays a strategic role in optimizing students' potential by not only presenting facts about nature but also fostering scientific thinking through observation, experimentation, and critical reasoning. In elementary education, science is essential for developing curiosity, critical thinking, and problem-solving skills, all of which are necessary for navigating daily life.

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Science education plays a vital role in fostering students' conceptual understanding and scientific process skills, while also shaping their attitudes toward learning. It equips students with methods for exploring natural phenomena through observation and experimentation, essential tools for developing critical thinking and problem-solving abilities (Harlen, 2010; DeBoer, 2019). As science and technology continue to advance rapidly, it is crucial that education prepares students to navigate these changes. Science learning not only helps students adapt but also enhances their ability to analyze and solve problems in everyday life (Jufrida et al., 2019). Moreover, science education benefits from being contextual and hands-on. By applying scientific concepts to real-life situations, students are able to make meaningful connections between their studies and the world around them. This approach also deepens their understanding and engagement with the material, as emphasized by Sutarto et al. (2021). To effectively engage students and make science both enjoyable and relevant, innovative teaching methods are essential. Creative strategies help bridge the gap between theory and practice, encouraging students to actively participate in their learning journey (Rahman et al., 2025).

Despite its importance, science education often faces challenges, particularly in helping students understand abstract concepts. Students' sensory experiences with science concepts can lead to varying interpretations, resulting in misconceptions (Anggraeni et al., 2024; Andayani & Subayani, 2025; Winarno et al., 2025). A common misconception arises in subjects such as the solar system, where the concepts are not only complex but also abstract and distant from students' everyday experiences. This issue is especially significant for elementary school students, who are still in the concrete operational stage of cognitive development, as described by Piaget (1972). At this stage, children are capable of logical thinking but are limited to real objects and situations they can directly observe. This limitation makes it particularly challenging for them to fully comprehend abstract concepts, such as those related to the solar system, which are not directly observable in their everyday lives.

The solar system, with its distant celestial objects and complex phenomena, presents a particular challenge in terms of student comprehension. As Zahara et al. (2020) notes, this subject is often difficult for students to understand because it involves abstract concepts that cannot be directly observed. These challenges highlight the need for interactive and engaging media to help students better understand these concepts. According to Urhan & Akpinar (2024), solar system learning is one of the subjects that requires special media to make it more accessible to students. Since most of the solar system's phenomena, such as planetary motion and the scale of celestial objects, cannot be directly observed, digital teaching materials are crucial. As Baysal et al. (2022) explain, these digital tools provide visual representations that help make abstract concepts more concrete and understandable for students.

Given the challenges in understanding abstract concepts like those in the solar system, there is an urgent need for innovative teaching tools that make learning more interactive and accessible. The development of digital media, particularly e-books, has gained significant attention in education, fuelled by rapid technological advancements. E-books offer a flexible and dynamic platform for presenting material, making it easily accessible through computers, smartphones, or laptops (Setiadi & Zainul, 2019). However, traditional e-books still face limitations in conveying abstract concepts. To address this gap, integrating Augmented Reality (AR) into e-books presents a transformative solution. AR-integrated e-books offer interactive multimedia elements that bring abstract concepts to life, offering students a more engaging and concrete learning experience, particularly for complex subjects like the solar system.

An electronic book (e-book) is a concept of a book in electronic format that can be operated using a computer and accessed via a student's smartphone or laptop anytime and anywhere (Apriantini & Sudiatmika, 2024). E-books are one of the learning resources through which students can access information related to the science content they are studying. E-books as a type of electronic teaching material, play an important role in supporting the learning process. Depdiknas (2008) defines e-books as teaching materials that can facilitate the achievement of effective, efficient, and easily accessible learning objectives for both teachers and students. E-books are a type of instructional material designed to be studied independently by students in the learning process. E-books contain systematically organized and engaging student materials designed to achieve the desired competencies, of course with the characteristics of electronic books (e-books) (Depdiknas, 2008). The presence of e-books not only motivates students and increases their interest in learning activities but also offers advantages over printed modules, such as interactivity that allows the presentation of images, animations, videos, and audio as supporting tools in understanding a subject.

The presence of e-books is considered very attractive because of their flexible and easy-to-use content, as well as being enriched with various displays and easy-to-use access (Momani et al., 2023). According to Sa'diah et al. (2022), the use of e-books can reduce paper usage and is easily accessible anytime and

anywhere by students. Additionally, e-books can be a solution when learning time is limited, allowing students to learn independently with ease and access the content via their smartphones or laptops.

In developing e-books, a design is needed that can motivate students to learn while also making it easier for them to understand abstract solar system material. To achieve this goal, e-books need to be interactive, incorporating features that provide a more realistic and meaningful learning experience. One medium that can be integrated into e-books is Augmented Reality (AR) technology. Augmented Reality technology allows students to view solar system objects in three dimensions directly through digital devices.

Augmented Reality technology is the integration of the real world with the virtual world in two-dimensional or three-dimensional form, projected into a real environment simultaneously (Mustaqim, 2017; Oktavianda et al., 2024). As stated by Barrow et al. (2019), Augmented Reality as a teaching tool has the ability to provide a learning experience that combines virtual and real environments or materials in the classroom. This allows students to learn in various ways by combining didactic, experimental, and kinesthetic learning.

Integrating Augmented Reality into e-books not only enhances visual appeal but also facilitates the understanding of abstract concepts through more realistic and interactive displays, making learning more effective, enjoyable, and relevant to the demands of the 21st century. A systematic review shows that AR-based learning media has proven effective in enhancing science concept understanding in elementary schools, providing engaging visualizations, and stimulating students' thinking skills (Siki & Leba, 2024). This indicates that integrating AR features into e-books is an innovative and beneficial approach to directly engaging students during the learning process.

Although the use of AR-based e-books has great potential to enhance student engagement and understanding, the integration of AR technology into e-book instructional materials remains limited. According to Yulyani et al. (2023), elementary school teachers primarily rely on government-issued printed textbooks and rarely utilize technology-based instructional materials. This reluctance is often due to constraints such as inadequate facilities, limited resources, and insufficient teacher skills in designing interactive media, resulting in a lack of AR-based teaching tools in schools.

The novelty of this research lies in the development of an Augmented Reality-integrated e-book specifically designed for the solar system subject, a topic often challenging for students to visualize and grasp fully. By integrating AR, this e-book offers an interactive and immersive experience that can bridge the gap between abstract concepts and students' understanding, something that traditional printed materials cannot achieve. This research is important because it addresses the gap in utilizing modern technology to enhance science education, especially in subjects like astronomy. The findings could offer valuable insights into how AR-based e-books can be successfully implemented in classrooms, overcoming the current barriers and providing an innovative approach to learning that aligns with the digital transformation in education.

## Method

This study uses a developmental research method. The product development model used in this study is carried out using stages adapted from the ADDIE model developed by Dick & Carey (1996), which consists of five stages, namely Analysis, Design, Development, Implementation, and Evaluation. The ADDIE development model was chosen because it aligns with the steps of the Multimedia Instructional Design Process developed by Lee & Owens (2004). This model was selected because it is systematic, structured, and flexible when applied to the development of technology-based instructional materials such as Augmented Reality.

The ADDIE development model consists of five stages, as illustrated in Figure 1.

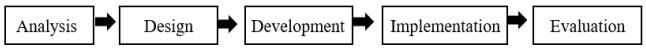



**Figure 1.** Stages of the ADDIE model (Dick & Carey, 1996)

The population of this study consists of all sixth-grade students from MIS PPI 323 Al-Hikmah. However, due to practical constraints, a sample of 30 students was selected. These students were chosen using purposive sampling, based on specific criteria relevant to the research objectives. This sampling technique ensures that the selected sample is representative of the broader population and can provide meaningful insights into the effectiveness of the Augmented Reality-integrated e-book.

**Table 1.** E-book feasibility criteria

| Average Percentage (%) | Interpretation |
|---|---|
| 90 ≤ RP | Very Good |
| 60 ≤ RP < 90 | Good |
| 30 ≤ RP < 60 | Not Good |
| RP < 30 | Very Bad |

Source: BSNP (2014)

Before the product was applied to students, the first step was to conduct a validation test on the teaching materials. This validation test involved five validators,

consisting of three science lecturers and two teachers. The purpose was to ensure that the developed product met the criteria for suitability in terms of content, language, presentation of material, and graphics. The instructional material validity sheet was adapted from the BSNP (2014) feasibility test. After obtaining the validation results, they were analyzed using the feasibility criteria for the product, which can be seen in Table 1.

The following section outlines the criteria used to evaluate the e-book's feasibility. The table above provides the interpretation based on the average percentage score (RP). A score of 90 or higher is considered "Very Good," indicating the e-book meets or exceeds the necessary standards. Scores between 60 and 90 are categorized as "Good," while scores below 60 are progressively rated as "Not Good" and "Very Bad," depending on how far they fall below the threshold.

The product underwent expert validation to ensure its compliance with necessary instructional standards. Five validators, including three science lecturers and two teachers, assessed the e-book's content, language, material presentation, and graphics. Based on their feedback, revisions were made to enhance the product's content and design. Following the validation, the e-book was trialled in a classroom setting during science lessons, specifically focusing on the solar system. The goal of this trial was to evaluate the effectiveness of the e-book and gauge the responses of both teachers and students. After using the product, students completed a questionnaire to assess material comprehension, visual appeal, ease of use, and perceived benefits. The responses from both the teacher and student questionnaires were then analyzed to determine the overall effectiveness of the e-book, using the following equation.

$$\text{Percentage} = \frac{\text{Total approval score}}{\text{Score ideal}} \times 100\% \quad (1)$$

The criteria for this test are as follows:

**Table 2.** Criteria for teacher and student responses

| Interval Percentage (%) | Interpretation |
|---|---|
| 76–100 | Very Good |
| 51–75 | Good |
| 36–50 | Enough |
| < 35 | Not Good |

Source: Sugiyono (2017)

## Result and Discussion

The development of an integrated Augmented Reality e-book on the solar system was carried out through the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) stages, with a description of each stage as follows.

*Analysis*

This research began with analyzing the learning outcomes of science lessons in sixth grade, then using the learning outcomes to formulate learning objectives and learning objectives flow. The formulation of learning outcomes and learning objectives flow was then used as a reference for developing solar system material in an e-book. The next stage was to analyze the characteristics of the material in sixth grade elementary school textbooks and collect sources relevant to solar system material. The material sources used in the e-book came from national and international scientific references to ensure the accuracy of the material. The content of the e-book was compiled based on the experiential learning approach proposed by Kolb (1984), which presents the material interactively and provides real experiences for students.

At this stage, a literature review was also conducted on integrated Augmented Reality (AR) e-books and their development to support science learning, particularly on solar system material in sixth grade elementary school. This literature review aimed to obtain data and information on e-book development and the applications used to integrate AR into e-books.

*Design*

At this stage, all ideas and concepts that have been designed in the analysis stage are then translated into detailed designs that will serve as a reference in the development of an integrated Augmented Reality e-book. In this second stage, several processes are carried out, including determining the topic and subtopics, organizing the material from simple to complex sections, dividing the content into smaller modules to make learning more structured, determining the Augmented Reality (AR) features that will appear to reinforce the concepts, designing the layout, page size, and font, adding visual elements such as infographics, tables, and interactive icons, arranging the placement of text and images, and integrating the AR features into the e-book to make them easily accessible to students.

In the creation of an AR-integrated e-book, the first step is to design 3D Augmented Reality objects using the Assemblr Edu platform. The integration of Augmented Reality (AR) technology into e-books aims to create interactive learning experiences that align with students' learning preferences. Augmented Reality can visualize 2D objects as 3D in real-time, thereby enhancing students' understanding of concepts. The Assemblr Edu platform was chosen as the medium for developing AR object designs due to its ability to dynamically display 3D models, animations, and multimedia. The following

is the initial display of the Assemblr Edu platform accessed via a laptop/PC.

The selection of Assemblr Edu as the platform for creating Augmented Reality objects was based on considerations of ease of use, relevance to learning, and the availability of features that support interactive learning. In addition, the Augmented Reality (AR) objects created can be easily embedded into e-books via QR codes or links. On the Assemblr platform, users can design the structure and layers of a solar system object. The results of creating these objects can be seen in Figure 3.

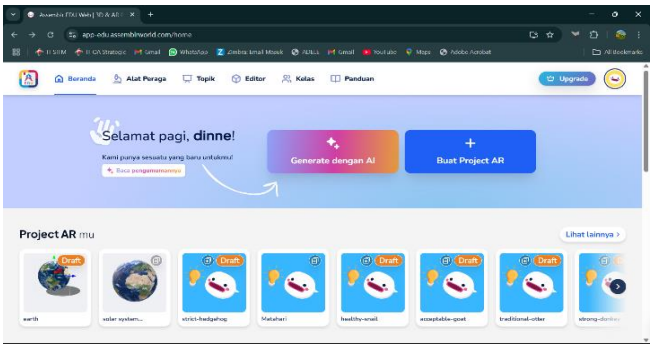



**Figure 2.** Assemblr Edu home screen


**Figure 3.** Model 3D Structure of the Sun's Layers

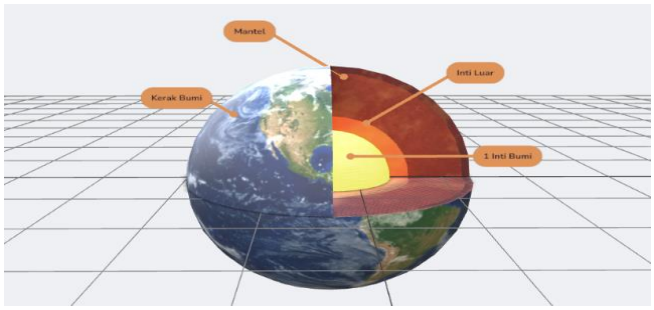



**Figure 4.** Model 3D structure of the earth's layers

Figures 3 and 4 show the layer structure on the sun and earth from the outer layer to the core. The object features interactive navigation buttons that allow students to see the structure of the sun and earth from the outer layer to the core more clearly. In addition, annotations are provided to display descriptions of each part of the sun's structure. The AR object showing the movement of planets relative to the sun can be seen in Figure 5.

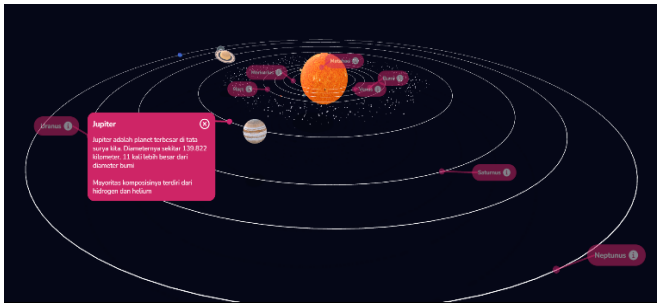



**Figure 5.** Planetary revolution around the sun

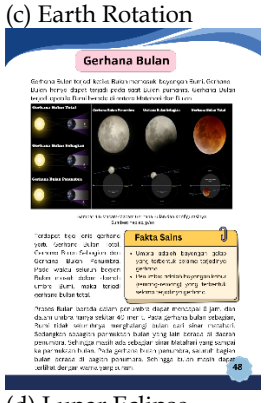
**Table 3**. Display of e-book AR


(a) Cover


(b) Sun


(c) Earth Rotation


(d) Earth Structure




(d) Lunar Eclipse


(e) Practice Questions

Figure 5 shows the positions of planets and celestial bodies relative to the sun, along with their movements. The Augmented Reality (AR) animation displayed in the figure allows students to observe the real-time process of a planet's revolution, accompanied by annotations providing descriptions of each planet.

After creating the AR objects using Assemblr Edu, the next step is to integrate the design into an interactive e-book format. Integration is done using the Canva platform, a graphic design platform that supports the creation of digital learning materials with visually appealing graphics. Using Canva allows researchers to systematically structure the e-book from the cover, table of contents, learning materials, to student questions. Canva's strength lies in its flexibility in combining text, images, icons, and interactive links, making it easy to place navigation features directly connected to AR animation content.

The results of the AR e-book development on solar system material are presented in Table 3.

*Development*

During the development stage, the Augmented Reality-integrated e-book that had been developed was then validated by experts (expert judgment) covering aspects of content feasibility, language, material presentation, and graphics. At this stage, validation was conducted by experienced expert validators, comprising 3 lecturers and 2 teachers. The validation process for the Augmented Reality-integrated e-book utilized an evaluation instrument in the form of a validation sheet with a 1-4 rating scale, accompanied by a column for improvement suggestions. The validation sheet used was based on the BSNP (National Education Standards Agency). This validation is conducted to ensure the alignment of the content, appearance, and technical aspects of the AR e-book with instructional material standards, as well as to incorporate expert feedback for improving and refining the product before its implementation in learning. These improvements collectively result in an AR e-book that is more informative and effective for use in science education. The cumulative assessment scores for each evaluability aspect evaluated by the validators can be seen in Table 4.

**Table 4.** Results of the feasibility assessment of augmented reality integrated e-books by expert validators

| Feasibility Aspects | Feasibility Value (%) | Category |
|---|---|---|
| Content | 95.00 | Very Good |
| Language | 94.54 | Very Good |
| Presentation | 91.60 | Very Good |
| Graphics | 92.33 | Very Good |
| Total | 93.36 | Very Good |

Based on Table 4, the results of the feasibility assessment of the Augmented Reality integrated e-book by expert validators show that overall the product is in the very good category with an average percentage of 93.3%. When viewed from each aspect, the content aspect obtained a feasibility score of 95.00%. This shows that the material presented is in accordance with basic competencies, indicators, and learning objectives. In the language aspect, a score of 94.54% was obtained, categorized as very good.

*Implementation*

At this stage, a trial of the integrated Augmented Reality e-book product that has been developed was conducted for 30 students in grade VI in solar system science lessons.

**Figure 6.** Trial phase in grade VI

In this phase, the teacher facilitated the learning process using the e-book as the primary resource, while students interacted directly with the Augmented Reality features to observe solar system objects in greater detail and with enhanced realism. The purpose of this pilot test was to assess the feasibility of the learning process and to evaluate student responses to the use of the AR-integrated e-book.

*Evaluation*

The evaluation stage is the final stage in the ADDIE development model. At this stage, teacher and student response questionnaires are administered to determine the effectiveness of AR-integrated e-book teaching materials based on the students' learning experiences. The responses from teachers and students are essential for improving the e-book in the learning process on science learning. The teacher responses are presented in Table 5.

Based on teachers' evaluations of the Augmented Reality (AR)-integrated e-book on the solar system, the teaching materials received overwhelmingly positive ratings across most aspects. For further details on the students' responses, refer to Table 6.

**Table 5.** Teacher responses

| Question Item | Score |
|---|---|
| The material presented in this e-book is easy to understand. | 5 |
| The images and text in the Augmented Reality integrated e-book are clear. | 5 |
| Easy to play. | 4 |
| Simple and understandable language. | 5 |
| Can arouse curiosity. | 5 |
| Can motivate students to learn. | 5 |
| The images in the Augmented Reality integrated e-book are attractive and clear. | 5 |
| Learning with the Augmented Reality-integrated e-book can make classroom learning active and enjoyable | 5 |
| Learning with the Augmented Reality-integrated e-book can help students understand the concepts of the solar system | 5 |
| Students can easily understand how to use the Augmented Reality-integrated e-book | 5 |

**Table 6.** Recapitulation of student responses

| Percentage Averages (%) | Category |
|---|---|
| 88.23 | Very Good |

Based on Table 6, it is known that the average response of students who have filled out the questionnaire regarding the assessment of learning using integrated Augmented Reality e-books reached a score Very Good according to the validation and feasibility criteria adapted from Sugiyono (2017).

The evaluation results of the AR-integrated e-book titled "Bringing Space into the Classroom: An AR-Integrated E-Book on the Solar System for Students in Elementary School" demonstrate the effectiveness of using Augmented Reality (AR) to enhance students' understanding and engagement with the material. The positive feedback from both teachers and students highlights the potential of AR technology as a powerful tool for teaching complex concepts such as the solar system in elementary school science education.

*Content Presentation*

With a score of 91.60% in content presentation, the e-book AR presents information about the solar system in a systematic and coherent manner. This ensures that students can easily grasp complex topics such as planetary orbits, celestial movements, and astronomical phenomena. AR technology allows students to visualize these abstract concepts in 3D, providing an interactive learning experience that traditional textbooks cannot offer (Aththibby et al., 2024; Crogman et al., 2025). This feature significantly contributes to better student understanding and engagement, as it transforms difficult concepts into more tangible, understandable experiences.

*Language Usage*

The language used in the AR e-book was found to be appropriate for elementary school students. Simple yet effective language allowed students to focus on understanding the content without being distracted by complicated vocabulary. The communicative and developmentally appropriate language used in the e-book helps bridge the gap in delivering scientific concepts to younger learners, thus enhancing both their learning experience and comprehension (Liu et al., 2024; Rudyarti et al., 2025).

*Graphic Design and Visuals*

The e-book AR achieved a score of 92.33% in graphics, reflecting the effectiveness of its visual presentation. The integration of AR to illustrate the solar system made the learning material more engaging, especially for students who benefit from visual learning. With interactive features, students could explore planets and other astronomical phenomena, which significantly enhanced their understanding. These visuals made the subject matter more interesting and accessible, reinforcing the importance of appealing graphics in science education. The combination of detailed AR visuals with interactive elements allowed students to engage with the material in an immersive and hands-on manner, which is highly beneficial for understanding complex scientific topics (Amirahma & Setyasto, 2024; Shah et al., 2024).

*Ease of Use*

Although the e-book AR performed excellently across many aspects, it received a slightly lower score of 4 (Good) in the "Ease of Use" category. This suggests that there are some technical areas, such as navigation and app responsiveness, that need further refinement. While these issues do not significantly affect the overall effectiveness of the e-book, addressing them would improve the user experience and make the application more intuitive for students. A smoother user interface would also help minimize any distractions or frustrations students may face when using the app, thus enhancing their learning experience (Hafizhah & Setyasto, 2024; Faudzi et al., 2024).

*Student Responses*

The students' responses to the AR-integrated e-book were overwhelmingly positive, with students rating it as "Very Good." This reflects how AR technology successfully captured students' interest and motivated them to engage more actively in the lesson. By allowing students to interact directly with the material, the AR e-book made learning more enjoyable and meaningful (Naf'atuzzahrah et al., 2024; Zhang). It helped students visualize difficult concepts like the solar system in a way

that was both educational and fun, encouraging curiosity and active participation. This level of engagement is crucial for fostering a deeper understanding of scientific concepts and promoting critical thinking among young learners.

The findings of this study highlight the potential of AR-integrated educational tools in revolutionizing science education, especially for younger students. By providing a more interactive and engaging learning experience, AR helps bridge the gap between abstract scientific concepts and students' understanding (Cahya & Bektiningsih, 2024). The use of AR not only enhances students' comprehension but also fosters a more engaging learning environment that encourages curiosity and active participation (Prananta et al., 2024; Rosyid & Setyasto, 2024). The positive feedback from both teachers and students emphasizes the effectiveness of AR in creating a dynamic and immersive learning experience. While technical improvements are needed in terms of app navigation and responsiveness, the overall success of the AR e-book suggests that AR has a significant role to play in the future of education, particularly in subjects like science that benefit from visual and interactive learning.

This study also points to the broader applicability of AR in education, particularly in enhancing learning in other subjects that require visualization and hands-on interaction. Further research could explore the long-term impact of AR on students' academic performance and motivation, especially in other scientific areas, and how it compares to traditional methods. Given its success in teaching the solar system, AR-integrated e-books could be a valuable tool for improving science education at the elementary level, helping students develop a stronger foundation in scientific concepts and fostering a love for learning.

## Conclusion

The developed Augmented Reality-integrated e-book is categorized as "very feasible" and has received an "excellent" response from students. This indicates that the e-book meets the necessary standards for teaching materials and effectively engages students. It bridges the gap between abstract concepts and students' understanding, making it a valuable and impactful tool for enhancing science education, particularly in the study of the solar system.

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**Author Contributions**
Main author and researcher of article, D.N.: conceptualization, methodology, e-book design creation, AR animation creation and development, creation and testing of research products, data processing and writing of the initial article, translator; research and second author of the article, D.R., N.W., and R.A.S: validation of instruments and initial product design before submission to expert validators for media and materials, supervisor who directed and guided the first author.

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## References

Amirahma, S., & Setyasto, N. (2024). Development of Augmented Reality-Assisted Teaching Materials in Science Subjects: Solar System Topic. *Jurnal Penelitian Pendidikan IPA*, *10*(5), 2346–2355. https://doi.org/10.29303/jppipa.v10i5.7027

Andayani, I. D., & Subayani, N. W. (2025). Penerapan Diferensiasi untuk Meningkatkan Penguasaan Konsep IPAS pada Siswa Sekolah Dasar. *Lentera Arfak: Jurnal Pendidikan dan Sains*, *3*(1), 39-50. Retrieved from https://jurnaljpsla.umpb.ac.id/index.php/LenteraArfak/article/view/20

Anggraeni, R., Andriana, E., & Syachruroji, A. (2024). Pengembangan Media Pembelajaran Augmented Reality untuk Meningkatkan Penguasaan Materi Sistem Pernapasan Manusia pada Pembelajaran IPA Kelas V SDN Serdang Kulon IV. *Elementary School*, *11*(1), 161–170. https://doi.org/10.31316/esjurnal.v11i1.4245

Apriantini, N. P., & Sudiatmika, A. I. A. R. (2024). Meta Analisis Pengaruh Penggunaan E-Book Terhadap Hasil Pembelajaran IPA. *JIPD (Jurnal Inovasi Pendidikan Dasar)*, *8*(1), 48–53. https://doi.org/10.36928/jipd.v8i1.1347

Aththibby, A. R., Rosa, F. O., Farida, N., & Prihandono, E. (2024). Development of Astronomy Learning Modules on the Subject of the Solar System Integrated with Augmented Reality Videos. *Jurnal Penelitian Pendidikan IPA*, *10*(5), 2760–2767. https://doi.org/10.29303/jppipa.v10i5.4873

Barrow, J., Forker, C., Sands, A., O'Hare, D., & Hurst, W. (2019). Augmented Reality for Enhancing Life Science Education. In *VISUAL 2019: The Fourth International Conference on Applications and Systems of Visual Paradigms* (pp. 1-8). IARIA.

Baysal, A. E., Ocak, İ., & Aydoğmuş, İ. (2022). Examining 5th Grade Students' Mental Models of Shadow, Solar Eclipse and Lunar Eclipse Through Drawings: A Case Study. *Journal of Turkish Science Education*, *19*(4), 1135-1154. https://doi.org/10.36681/tused.2022.166

BSNP. (2014). *Instrumen Penilaian Buku Teks Pelajaran*. Jakarta: Badan Standar Nasional Pendidikan.

Cahya, K. L., & Bektiningsih, K. (2024). Development of Augmented Reality Based Flipbook Media on Natural Science Subject Matter of Ecosystems. *Jurnal Penelitian Pendidikan IPA*, *10*(11), 8436–8445. https://doi.org/10.29303/jppipa.v10i11.7630

Crogman, H. T., Cano, V. D., Pacheco, E., Sonawane, R. B., & Boroon, R. (2025). Virtual Reality, Augmented Reality, and Mixed Reality in Experiential Learning: Transforming Educational Paradigms. *Education Sciences*, *15*(303), 1-23. https://doi.org/10.3390/educsci15030303

DeBoer, G. (2019). *A History of Ideas in Science Education*. Teachers College Press.

Depdiknas. (2008). *Kurikulum Tingkat Satuan Pendidikan (KTSP)*. Jakarta: Departemen Pendidikan Nasional.

Dick, W., & Carey, L. (1996). *The Systematic Design of Instruction* (4th ed.). New York: Harper Collins College Publishers.

Faudzi, M. A., Cob, Z. C., Ghazali, M., Omar, R., & Sharudin, S. A. (2024). User Interface Design in Mobile Learning Applications: Developing and Evaluating a Questionnaire for Measuring Learners' Extraneous Cognitive Load. *Heliyon*, *10*(18), e37494. https://doi.org/10.1016/j.heliyon.2024.e37494

Hafizhah, F. J., & Setyasto, N. (2024). Augmented Reality-Assisted Scrapbook Media Development in Natural and Social Science Learning. *Jurnal Penelitian Pendidikan IPA*, *10*(7), 4149–4157. https://doi.org/10.29303/jppipa.v10i7.7258

Harlen, W. (2010). *Principles and Big Ideas of Science Education*. Hatfield: Association for Science Education.

Jufrida, J., Basuki, F. R., Sawitri, E., & Afriani, E. (2019). Need Analysis of Science Textbook Based on Jambi Local Wisdom to Improve Students' Science Literacy of SMPN 7 Muaro Jambi. *Formatif: Jurnal Ilmiah Pendidikan MIPA*, *9*(2), 151–160. https://doi.org/10.30998/formatif.v9i2.3340

Kolb, D. A. (1984). *Experiential Learning: Experience as the Source of Learning and Development*. Englewood Cliffs, NJ: Prentice Hall. Retrieved from http://academic.regis.edu/ed205/Kolb.pdf

Lee, W. W., & Owens, D. L. (2004). *Multimedia-Based Instructional Design: Computer-Based Training, Web-Based Training, Distance Broadcast Training, Performance-Based Solutions* (2nd ed.). San Francisco: Pfeiffer.

Liu, S., Reynolds, B. L., Thomas, N., & Soyoof, A. (2024). The Use of Digital Technologies to Develop Young Children's Language and Literacy Skills: A Systematic Review. *SAGE Open*, *14*(1), 1-18. https://doi.org/10.1177/21582440241230850

Momani, M. A. K. A., Alharahasheh, K. A., & Alqudah, M. (2023). Digital Learning in Sciences Education: A Literature Review. *Cogent Education*, *10*, 2277007, 1-19. https://doi.org/10.1080/2331186X.2023.2277007

Mustaqim, I. (2017). Pemanfaatan Augmented Reality dalam Pembelajaran. *Jurnal Pendidikan Teknologi dan Kejuruan*, *13*(2), 174–183. https://doi.org/10.23887/jptk-undiksha.v13i2.8525

Naf'atuzzahrah, N., Hadiprayitno, G., & Harjono, A. (2024). Validity of Project Model Science Learning Tools Assisted by Augmented Reality to Improve Students' Literacy and Creative Thinking Abilities. *Jurnal Penelitian Pendidikan IPA*, *10*(8), 5837–5843. https://doi.org/10.29303/jppipa.v10i8.8373

Oktavianda, N., Rahmatan, H., Huda, I., Pada, A. U. T., Safrida, S., & Deviani, R. (2024). Implementation of Augmented Reality (AR) Animation Media to Enhance Learning Outcomes and Interest in the Excretory System Topic. *Jurnal Penelitian Pendidikan IPA*, *10*(11), 8359–8365. https://doi.org/10.29303/jppipa.v10i11.8816

Piaget, J. (1972). *The Psychology of the Child*. New York: Basic Books.

Prananta, A. W., Rohman, A., Agustin, R., & Pranoto, N. W. (2024). Augmented Reality for Interactive, Innovative and Fun Science Learning: Systematic Literature Review. *Jurnal Penelitian Pendidikan IPA*, *10*(SpecialIssue), 45–51. https://doi.org/10.29303/jppipa.v10iSpecialIssue.7519

Rahman, A. W., Indahyanti, R., & Nur, S. (2025). EFL Teachers' Challenges in Developing Interactive Teaching Material for Senior High School Students. *English Education Journal*, *10*(2), 93–97. https://doi.org/10.55340/e2j.v10i2.1726

Rosyid, Y. R. R., & Setyasto, N. (2024). Development of Android-Based Augmented Reality Learning Media on the Human Respiratory System to Improve Student Learning Outcomes. *Jurnal Penelitian Pendidikan IPA*, *10*(5), 2503–2510. https://doi.org/10.29303/jppipa.v10i5.7024

Rudyarti, E., Sulandari, U., & Purba, Y. S. (2025). Web-Based Climate Change Disease Diagnosis Expert System Using Forward Chaining Method. *Jurnal Penelitian Pendidikan IPA*, *11*(7), 67–75. https://doi.org/10.29303/jppipa.v11i7.11891

Sa'diah, S., Ruhiat, Y., & Sholih, S. (2022). Pengembangan E-Modul Interaktif Berbasis

Augmented Reality untuk Siswa Sekolah Dasar. *VOX EDUKASI: Jurnal Ilmiah Ilmu Pendidikan*, *13*(1), 21–29. https://doi.org/10.24036/ekj.v1i1.104019

Setiadi, T., & Zainul, R. (2019). Pengembangan E-Modul Asam Basa Berbasis Discovery Learning untuk Kelas XI SMA/MA. *EduKimia*, *1*(1), 1-9. https://doi.org/10.24036/ekj.v1i1.104019

Shah, S. F. A., Ghadi, Y. Y., Mazhar, T., Hamam, H., Shahzad, T., & Khan, M. A. (2024). Integrating Educational Theories with Virtual Reality: Enhancing Engineering Education and VR Laboratories. *Social Sciences & Humanities Open*, *10*, 101207, 1-14. https://doi.org/10.1016/j.ssaho.2024.101207

Sihombing, R. A., Wahidin, N. R., Rahmat, A., Winarno, N., Hamdiyati, Y., & Liu, S.-Y. (2025). Discovering the Relationship: Self-Efficacy, Metacognitive Awareness, and Science Learning Processes in Indonesian Science Classrooms. *Journal of Educational, Cultural and Psychological Studies (ECPS)*, *31*, 111–129. https://doi.org/10.7358/ecps-2025-031-siho

Siki, I. M., & Leba, S. M. R. (2024). A Systematic Review: The Use of Augmented Reality to Improve Science Learning in Elementary School. *Journal of Physics: Conference Series*, *2892*(1), 012042. https://doi.org/10.1088/1742-6596/2892/1/012042

Sugiyono, S. (2017). *Metode Penelitian Kuantitatif, Kualitatif, dan R&D*. Bandung: CV Alfabeta.

Sutarto, S., Lufri, L., Laili, F., Anhar, A., Chotimah, C., & Festiyed, F. (2021). Development of Student Worksheets Based on STEM Approach to Improve Students' Critical Thinking Skills. *Journal of Physics: Conference Series*, *2104*, 012009. https://doi.org/10.1088/1742-6596/2104/1/012009

Urhan, O., & Akpinar, E. (2024). The Views of Students Regarding the Use of Virtual Reality Applications in Elementary Science Classes. *Science Insights Education Frontiers*, *21*(1), 3329–3348. https://doi.org/10.15354/sief.24.or550

Winarno, N., Afifah, R. M. A., Sihombing, R. A., Firdaus, R. A., & Damopolii, I. (2025). Analyzing Misconceptions Using a Four-Tier Test on the Topic of Vibration: A Survey of Pre-Service Science Teachers. *Unnes Science Education Journal*, *14*(1), 1–15. https://doi.org/10.15294/usej.v13i1.20612

Yulyani, Y., Miaz, Y., Fitria, Y., & Hidayati, A. (2023). Practicality of Using Interactive Multimedia Teaching Materials with a STEM Approach in Elementary Schools. *Jurnal Penelitian Pendidikan IPA*, *9*(10), 8636–8640. https://doi.org/10.29303/jppipa.v9i10.5743

Zahara, A., Feranie, S., Winarno, N., & Siswantoro, N. (2020). Discovery Learning with the Solar System Scope Application to Enhance Learning in Middle School Students. *Journal of Science Learning*, *3*(3), 174–184. https://doi.org/10.17509/jsl.v3i3.23503

Zhang, X., Tlili, A., Shubeck, K., Hu, X., Huang, R., & Zhu, L. (2021). Teachers' Adoption of an Open and Interactive E-Book for Teaching K-12 Students Artificial Intelligence: A Mixed Methods Inquiry. *Smart Learning Environments*, *8*(1), 1-20. https://doi.org/10.1186/s40561-021-00176-5