



Development of Interactive Digital Books with Augmented Reality and Virtual Reality in Plant Physiology

Aulia Afza^{1*}, Diana Susanti¹, Nursyahra¹, Mourend Defegi², Bambang Supriatno³, Riandi³

¹Department of Biology Education, Universitas PGRI, Padang, Indonesia.

²Department of Technology Information, Universitas PGRI, Padang, Indonesia.

³Department of Biology Education, Universitas Pendidikan Indonesia, Padang, Indonesia.

Received: December 05, 2025

Revised: January 12, 2026

Accepted: February 25, 2026

Published: February 28, 2026

Corresponding Author:

Aulia Afza

dianasusantimpd@yahoo.co.id

DOI: [10.29303/jppipa.v12i2.13729](https://doi.org/10.29303/jppipa.v12i2.13729)

 Open Access

© 2026 The Authors. This article is distributed under a (CC-BY License)



Abstract: Plant Physiology is a compulsory course in the biology and biology education study program. The material has a high conceptual complexity, presenting physiological processes, including biochemistry, cellular biology, molecular, genetics, and environmental interactions which constitute the complexity of science. Interdisciplinary, requiring students to integrate knowledge from various disciplines. Interviews revealed that the material is complex, encompassing the study of cells, anatomy, biochemistry, and their relationship to the environment. The available teaching materials are primarily PowerPoint presentations. Lecturers lack teaching materials that adequately explain the mechanisms that occur within the plant body. One effective approach is to utilize interactive digital textbooks equipped with Augmented Reality (AR) and Virtual Reality (VR). This research aims to develop an interactive digital with AR and VR for the Plant Physiology. This research is a developmental study using the 4D model. This study was limited to the development stage, which aimed to determine the validity of the digital book. The instrument used was a digital book validity analysis questionnaire. Data analysis used the percentage formula. The results of the study show that the interactive digital book equipped with AR and VR in the plant physiology course is valid with a validation value of 91.82%.

Keywords: Augmented reality; Interactive digital book; Plant physiology; Virtual reality

Introduction

Plant Physiology is a compulsory course in the biology and biology education study program. The material has a high conceptual complexity, presenting physiological processes, including biochemistry, cellular biology, molecular, genetics, and environmental interactions which constitute the complexity of science (Dejonghe & Russinova, 2017). Interdisciplinary, requiring students to integrate knowledge from various discipline (Ausubel, 2002). Difficulties are also encountered with the concepts of osmosis and plasmolysis (Mauro et al., 2003). Misunderstandings about the role of carbon dioxide and sugar in the (Jančaříková & Jančařík, 2022). This hinders students' ability to understand more advanced concepts that build

on the basic knowledge of photosynthesis. Interviews revealed that the material is complex, encompassing the study of cells, anatomy, biochemistry, and their relationship to the environment. The available teaching materials are primarily PowerPoint presentations. Lecturers lack teaching materials that adequately explain the mechanisms that occur within the plant body. One effective approach is to utilize interactive digital textbooks equipped with Augmented Reality (AR) and Virtual Reality (VR).

AR is a technology that combines digital elements with the real world (Crogman et al., 2025). AR is more effective in conveying auditory information (Huang et al., 2019), offering real-time guidance that increases the speed of task completion (Pinto & Huertas, 2025), enabling the use of real-world tools, increasing user

How to Cite:

Afza, A., Susanti, D., Nursyahra, Defegi, M., Supriatno, B., & Riandi. Development of Interactive Digital Books with Augmented Reality and Virtual Reality in Plant Physiology. *Jurnal Penelitian Pendidikan IPA*, 12(2), 74-79. <https://doi.org/10.29303/jppipa.v12i2.13729>

satisfaction (Lisle et al., 2023). Users can view virtual objects in 2D and 3D that appear like the real world through the aid of a camera, smartphone, computer webcam, tablet or special devices such as AR glasses or headsets. The use of AR is able to equip students with contextual experiences in understanding lecture material (Lisle et al., 2023). AR can improve the learning process and student interest in learning because AR itself has entertainment aspects that can increase interest and project it in real terms by involving the interaction of all five student senses. VR is a technology that creates a completely artificial environment, providing a realistic and/or believable experience synthetically or virtually (Shen & Shirmohammadi, 2008). On the other hand, VR creates a simulated three-dimensional (3D) environment that allows users to explore and interact with the virtual environment.

Research results show that the use of AR shows significant results regarding the integration of AR and VR technology to enhance the learning experience (Al-Ansi et al., 2023; Bermejo et al., 2023). Research results show that interactive digital books have been proven to improve students' representation skills in traditional methods (Panuqih et al., 2024). Improved student learning outcomes and demonstrated their effectiveness in facilitating a more in-depth learning experience (Xu et al., 2023). Allowing students to visualize and interact with content in ways that traditional texts cannot provide (Pineda et al., 2022). So, students learn at their own pace and access material anytime and anywhere and are able to develop literacy skills (López-Escribano et al., 2021). Looking at the existing research evidence, it is hoped that this innovation has enormous potential to improve students' learning experiences. Related research on digital textbooks integrating AR and VR has shown that Bio-Meta is well-received and suitable for use as a learning medium (Abbas Shah et al., 2024).

The development of AR-based learning media for photosynthesis facilitates user interaction in real-world settings (Istmadelia & Tyas, 2024; Singh & Ahmad, 2024). AR-based flipbooks provide an interactive and

engaging learning experience for students (Mohideen, 2024). The integration of AR and VR technology into interactive digital textbooks offers significant potential for improving the quality of lectures, making the material more engaging and interactive, and helping students better understand complex concepts. This research aims to develop an interactive digital textbook equipped with AR and VR for the Plant Physiology course.

Method

This research is a developmental study using the 4D model (Azzahra & Ninawati, 2024). This study was limited to the development stage, which aimed to determine the validity of the digital book. The instrument used was a handout validity analysis questionnaire. The questionnaire was completed by seven validators. The data analysis technique used the percentage formula:

$$V = \frac{\text{scores obtained}}{\text{minimum score}} \times 100\% \tag{1}$$

Based on the obtained V value, validity criteria are established as shown in Table 1:

Table 1. Validity Criteria

Validation Score	Category
0 - 20	Invalid
21 - 40	less
41 - 60	Enough
61 - 80	Valid
81 - 100	Very valid

Result and Discussion

Validity testing was conducted by several expert lecturers using a validity questionnaire instrument. The validity questionnaire indicators included material, media, and language. The validity data can be seen in Table 2.

Table 2. Validity Results of Digital Books Equipped with Augmented Reality (AR) and Virtual Reality (VR) in the Plant Physiology

Aspect	Validator							Total	Validation Score (%)	Criteria
	1	2	3	4	5	6	7			
Language	36	39	33	39	35	36	38	256	91.43	Very valid
Material	63	71	70	71	62	58	70	465	92.26	Very valid
Media	72	78	78	80	70	59	77	514	91.79	Very valid
275.48%										
91.82%										Very valid

Based on Table 2, it can be seen that the digital book equipped with AR and VR that was developed has met the product validity requirements. For the language

aspect, the validation value of the digital book equipped with AR and VR is 91.43% (very valid). For the material aspect, the validation value of the digital book equipped

with AR and VR is 92.26% (very valid). For the media aspect, the validation value of the digital book equipped with AR and VR is 91.79% (very valid). The average validation value of the digital book equipped with AR and VR is 91.82% (very valid). In terms of language, digital books equipped with AR and VR are declared valid because the language used complies with the Indonesian Spelling Standards (EBI). Good and clear language is language that meets the communication needs of language learning. Correct language is language that complies with linguistic rules (Binder et al., 2022).

In addition, the effective choice of words and sentences makes this digital book easy to understand for readers. The digital book also contains consistent terms and symbols so as not to confuse readers. Effective sentences are clear, concise, and straightforward sentences so that they can be easily understood by students. Effective sentences are sentences that are not ambiguous and do not obscure the meaning (Frances, 2024). By using the right language rules, the information from this digital book equipped with AR and VR will be conveyed well. For the material aspect, digital books equipped with AR and VR are declared valid because they contain physiology material correctly. The presentation of AR and VR is in accordance with the truth of the material and is presented in an interesting way. In addition, the level of depth of the material is in accordance with the category of higher education. Digital books not only present information textually, but are able to enrich the learning experience and various learning styles of students (Natsir et al., 2022), self-regulated learning that provides interactive and multimodal resources (Mashfufah et al., 2019) users experience learning in a more immersive way (Engberg et al., 2018).

AR combines digital elements with the real world (Krichenbauer et al., 2018). VR creates a fully digital environment, students can explore plant ecosystems and biological interactions in realistic simulations, which increases user comfort and interaction (Agarwal et al., 2024; Selvan et al., 2024). Use of the product increases student motivation and engagement (Hari et al., 2025; Nikou, 2024), interacting with real-time stories creates new conventions for multimedia experiences that transition smoothly between discursive and immersive modes. For the media aspect, digital books equipped with AR and VR are declared valid because they have presented good fonts, layouts and writing combinations that are easy to read. In addition, the color degradation used in digital books is good and attractive to readers. The use of varied colors aims to attract attention and interest, but also considers user comfort (Dou et al., 2025). Then, images and AR and VR already have an emphasis on the learning objectives to be achieved. In

compiling teaching materials, it is necessary to include clear illustrations and images so that students can see the actual material being studied (Kooijmans et al., 2024; Scherer et al., 2023). The development of interactive digital textbooks equipped with AR and VR brings innovation to learning design, enhancing students' understanding of complex, engaging, and interactive concepts (Oo et al., 2024).

The main innovation is the availability of digital textbooks with the ability to visualize physiological processes in real time. AR can visualize difficult-to-understand 3D models through text or images, reinforcing understanding through an immersive visual experience. VR, conducting virtual experiments in complex environments (Yingsoon et al, 2024) provides opportunities to learn from mistakes in simulations bridging the gap between theoretical knowledge and practical application in educational settings (Lawson et al., 2025; Ding, 2024). This innovation also supports collaborative learning, collaborating on interactive projects, sharing knowledge, discussing findings, and providing feedback to build a collective understanding of the material being taught (Osmani & Murati, 2024; Shofa et al., 2024; Farika et al., 2024; Ghafar, 2024). The development of interactive digital textbooks with AR and VR not only introduces a more modern and effective learning design but also prepares students to face real-world challenges with better skills and deeper understanding.

Conclusion

Based on the research, it can be concluded that interactive digital books equipped with AR and VR have been developed and are valid. This digital book meets product validity requirements and brings key innovations in Plant Physiology learning, namely: Real-Time Visualization: AR visualizes difficult-to-understand 3D models through text/images, while VR creates a fully digital environment for virtual exploration and experimentation; Enhanced Understanding: AR/VR enhances students' understanding of complex concepts, bridging the gap between theoretical knowledge and practical application; Engagement and Motivation: The use of this interactive product increases students' motivation and engagement; Supports Collaborative Learning: This new format facilitates interactive projects, knowledge sharing, and discussions.

Acknowledgements

The author would like to thank the Direktorat Penelitian dan Pengabdian Masyarakat (DPPM) Kemdiktisaintek for funding this research.

Author Contributions

Conceptualization and methodology, writing—original draft preparation, supervision, A.A and D.S.; software and validation, M.D., formal analysis and data curation, A.A. and D.S., writing –review and editing, B.S., R. and N.S.; visualization, A.A.

Funding

This research was funded by the Direktorat Penelitian dan Pengabdian Masyarakat (DPPM) Kemdiktisaintek.

Conflicts of Interest

The authors declare that there is no conflict of interest in this article

References

- Abbas Shah, S. F., Mazhar, T., Shahzad, T., Khan, M. A., Ghadi, Y. Y., & Hamam, H. (2024). Integrating educational theories with virtual reality: Enhancing engineering education and VR laboratories. *Social Sciences & Humanities Open*, *10*, 101207. <https://doi.org/10.1016/j.ssaho.2024.101207>
- Agarwal, R., Tatrari, P., & Jain, S. (2024). Augmented and virtual realities: A comprehensive survey, current advancements, and future technologies for immersive technologies in industry and beyond. In *Challenges in Information, Communication and Computing Technology* (1st ed., pp. 661–665). CRC Press. <https://doi.org/10.1201/9781003559092-114>
- Al-Ansi, A. M., Jaboob, M., Garad, A., & Al-Ansi, A. (2023). Analyzing augmented reality (AR) and virtual reality (VR) recent development in education. *Social Sciences & Humanities Open*, *8*(1), 100532. <https://doi.org/10.1016/j.ssaho.2023.100532>
- Ausubel, F. M. (Ed.). (2002). Summaries of National Science Foundation-Sponsored Arabidopsis 2010 Projects and National Science Foundation-Sponsored Plant Genome Projects That Are Generating Arabidopsis Resources for the Community. *Plant Physiology*, *129*(2), 394–437. <https://doi.org/10.1104/pp.900034>
- Azzahra, S. R., & Ninawati, M. (2024). Development of Pop-Up Book Media Based on Contextual Content of Science Learning Material on Animal Life Cycle In Elementary School. *Eduvest - Journal of Universal Studies*, *4*(4), 2148–2158. <https://doi.org/10.59188/eduvest.v4i4.1291>
- Bermejo, B., Juiz, C., Cortes, D., Oskam, J., Moilanen, T., Loijas, J., Govender, P., Hussey, J., Schmidt, A. L., Burbach, R., King, D., O'Connor, C., & Dunlea, D. (2023). AR/VR Teaching-Learning Experiences in Higher Education Institutions (HEI): A Systematic Literature Review. *Informatics*, *10*(2), 45. <https://doi.org/10.3390/informatics10020045>
- Binder, M., Heinrich, B., Hopf, M., & Schiller, A. (2022). Global reconstruction of language models with linguistic rules – Explainable AI for online consumer reviews. *Electronic Markets*, *32*(4), 2123–2138. <https://doi.org/10.1007/s12525-022-00612-5>
- 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*(3), 303. <https://doi.org/10.3390/educsci15030303>
- Dejonghe, W., & Russinova, E. (2017). Plant Chemical Genetics: From Phenotype-Based Screens to Synthetic Biology. *Plant Physiology*, *174*(1), 5–20. <https://doi.org/10.1104/pp.16.01805>
- Ding, S. (2024). The Practice and Exploration of Virtual Reality Technology in Distance Education. *Journal of Contemporary Educational Research*, *8*(12), 57–62. <https://doi.org/10.26689/jcer.v8i12.9170>
- Dou, X., Zhang, Y., Fan, Q., Liu, Y., & Liu, M. (2025). An Empirical Analysis of the Emotional Evaluation of Virtual Reality Architectural Interior Colors Based on Personality Differences. *Buildings*, *15*(24), 4525. <https://doi.org/10.3390/buildings15244525>
- Engberg, M., David Bolter, J., & MacIntyre, B. (2018). RealityMedia: An Experimental Digital Book in WebXR. *2018 IEEE International Symposium on Mixed and Augmented Reality Adjunct (ISMAR-Adjunct)*, 324–327. <https://doi.org/10.1109/ISMAR-Adjunct.2018.00096>
- Farika, M., Samosir, F. T., & Sa'diyah, L. (2024). Utilization of E-Books in E-Library Applications to Improve Digital Literacy of Librarians. *JlPI (Jurnal Ilmu Perpustakaan Dan Informasi)*, *9*(2), 244. <https://doi.org/10.30829/jlpi.v9i2.18654>
- Frances, C. (2024). Good enough processing: What have we learned in the 20 years since Ferreira et al. (2002)? *Frontiers in Psychology*, *15*, 1323700. <https://doi.org/10.3389/fpsyg.2024.1323700>
- Ghafar, Z. (2024). The Impact of Electronic Books on Learning English Language in the Digital Era: An Overview. *Journal of Digital Learning and Distance Education*, *2*(7), 635–644. <https://doi.org/10.56778/jdlde.v2i7.184>
- Hari, D., Skrbinjek, V., & Flogie, A. (2025). Enhancing Student Motivation and Engagement Through the Use of a Slovenian-Speaking Social Robot AlphaMini. *Education Sciences*, *15*(9), 1222. <https://doi.org/10.3390/educsci15091222>
- Huang, K.-T., Ball, C., Francis, J., Ratan, R., Boumis, J., & Fordham, J. (2019). Augmented Versus Virtual Reality in Education: An Exploratory Study

- Examining Science Knowledge Retention When Using Augmented Reality/Virtual Reality Mobile Applications. *Cyberpsychology, Behavior, and Social Networking*, 22(2), 105–110. <https://doi.org/10.1089/cyber.2018.0150>
- Istmadelia, M. Q., & Tyas, D. N. (2024). Development of Augmented Reality-Based Digital Learning Media for Grade V Elementary School on the Topic of Food Chains. *Jurnal Penelitian Pendidikan IPA*, 10(11), 9180–9188. <https://doi.org/10.29303/jppipa.v10i11.7362>
- Jančaříková, K., & Jančařík, A. (2022). How to Teach Photosynthesis? A Review of Academic Research. *Sustainability*, 14(20), 13529. <https://doi.org/10.3390/su142013529>
- Kooijmans, R., Dalemans, R., Van Der Spek, J., Staaks, J., Langdon, P. E., & Moonen, X. (2024). Does adding pictures to easy-to-read texts benefit comprehension for people with reading difficulties? A meta-analytic review. *Evidence-Based Communication Assessment and Intervention*, 18(4), 133–159. <https://doi.org/10.1080/17489539.2025.2551910>
- Krichenbauer, M., Yamamoto, G., Taketom, T., Sandor, C., & Kato, H. (2018). Augmented Reality versus Virtual Reality for 3D Object Manipulation. *IEEE Transactions on Visualization and Computer Graphics*, 24(2), 1038–1048. <https://doi.org/10.1109/TVCG.2017.2658570>
- Lawson, E., Carter, L., Johnson, A., & Baston, G. (2025). *Integrating Virtual Reality and Cognitive Neuroscience: Enhancing Learning Outcomes Through α 5-GABAA Receptor Modulation*. Open Science Framework. <https://doi.org/10.31219/osf.io/peb2u>
- Lisle, L., Davidson, K., Gitre, E. J. K., North, C., & Bowman, D. A. (2023). Different realities: A comparison of augmented and virtual reality for the sensemaking process. *Frontiers in Virtual Reality*, 4, 1177855. <https://doi.org/10.3389/frvir.2023.1177855>
- López-Escribano, C., Valverde-Montesino, S., & García-Ortega, V. (2021). The Impact of E-Book Reading on Young Children's Emergent Literacy Skills: An Analytical Review. *International Journal of Environmental Research and Public Health*, 18(12), 6510. <https://doi.org/10.3390/ijerph18126510>
- Mauro, M. A., De Queiroz Tavares, D., & Menegalli, F. C. (2003). Behavior of plant tissue in osmotic solutions. *Journal of Food Engineering*, 56(1), 1–15. [https://doi.org/10.1016/S0260-8774\(02\)00107-3](https://doi.org/10.1016/S0260-8774(02)00107-3)
- Mohideen, H. L. M. (2024). Exploring the Opportunities of Implementing Artificial Intelligence (AI) Technology for Teaching Arabic to Non-Native Speakers: A Theoretical Approach. *Journal of Digital Learning And Distance Education*, 2(10), 760–767. <https://doi.org/10.56778/jdlde.v2i9.225>
- Natsir, I., Taufik, A. R., & Ruslau, M. F. V. (2022). Pelatihan Pembuatan Buku Digital Berbantuan Flipbook Maker Sebagai Bahan Ajar Inovatif Bagi Guru Di Smp Negeri Buti. *Jubaedah: Jurnal Pengabdian Dan Edukasi Sekolah (Indonesian Journal of Community Services and School Education)*, 2(1), 1–8. <https://doi.org/10.46306/jub.v2i1.52>
- Nikou, S. A. (2024). Student motivation and engagement in maker activities under the lens of the Activity Theory: A case study in a primary school. *Journal of Computers in Education*, 11(2), 347–365. <https://doi.org/10.1007/s40692-023-00258-y>
- Oo, T. Z., Kadyirov, T., Kadyirova, L., & Józsa, K. (2024). Design-based learning in higher education: Its effects on students' motivation, creativity and design skills. *Thinking Skills and Creativity*, 53, 101621. <https://doi.org/10.1016/j.tsc.2024.101621>
- Osmani, R., & Murati, R. (2024). The Positive And Negative Sides Of The Digital Book As An Aid For The Realization Of Learning In School Year 2021-2022 In Fourth Grade. *Journal of Educational Research - Education*, 6(11–12), 208–216. <https://doi.org/10.62792/ut.education.v6.i11-12.p2658>
- Panuqih, F. W. A., Istiyono, E., & Jumadi, J. (2024). Effect of Interactive E-Book to Measure Mathematical Representations on Optics in High School. *Jurnal Penelitian Pendidikan IPA*, 10(9), 6947–6954. <https://doi.org/10.29303/jppipa.v10i9.6507>
- Pineda, M., García, O., Aguilar, A., & León, F. (2022). Elaboration of an Interactive Electronic Book of Measures of Central Tendency. *Education and New Developments*, 2, 294–298. <https://doi.org/10.36315/2022v2end067>
- Pinto, I., & Huertas, A. (2025). A comparative study of VR and AR heritage applications on visitor emotional experiences: A case study from a peripheral Spanish destination. *Virtual Reality*, 29(1), 36. <https://doi.org/10.1007/s10055-025-01109-0>
- Scherer, D., Verkühlen, A., & Dutke, S. (2023). Effects of related decorative pictures on learning and metacognition. *Instructional Science*, 51(4), 571–594. <https://doi.org/10.1007/s11251-023-09618-8>
- Selvan, C., Vidhya, K., Senthil Kumar, R., & Veningston, K. (2024). Comparative Overview of Augmented Reality, Virtual Reality, and Mixed Reality: In *Advances in Medical Technologies and Clinical Practice* (pp. 1–16). IGI Global. <https://doi.org/10.4018/979-8-3693-1123-3.ch001>
- Shen, X., & Shirmohammadi, S. (2008). Virtual and Augmented Reality. In *Encyclopedia of Multimedia*

- (pp. 962-967). Springer US.
https://doi.org/10.1007/978-0-387-78414-4_253
- Shofa, G. Z., Zulaikah, Pratama, A., Mauliana, R., & Saputra, I. (2024). Analisis Pengaruh Penggunaan Buku Digital (E-Book) Terhadap Minat Dan Kebiasaan Membaca Mahasiswa Universitas Nurul Huda. *Jurnal Pendidikan & Pengajaran (JUPE2)*, 2(2), 305-317.
<https://doi.org/10.54832/jupe2.v2i2.354>
- Singh, G., & Ahmad, F. (2024). An interactive augmented reality framework to enhance the user experience and operational skills in electronics laboratories. *Smart Learning Environments*, 11(1), 5.
<https://doi.org/10.1186/s40561-023-00287-1>
- Xu, X., Shi, Z., Bos, N. A., & Wu, H. (2023). Student engagement and learning outcomes: An empirical study applying a four-dimensional framework. *Medical Education Online*, 28(1), 2268347.
<https://doi.org/10.1080/10872981.2023.2268347>