



Development of E-Booklet Learning Media on Classification of Living Organisms to Improve Scientific Literacy in High School Students

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Abstract: This study aims to develop and validate an e-booklet-based learning medium on the classification of living organisms to enhance scientific literacy among high school students. The study employed a Research and Development (R&D) method using a modified Borg and Gall development model consisting of five stages: (1) identifying potentials and problems, (2) data collection, (3) product design, (4) design validation, and (5) design revision. The developed e-booklet was validated by a panel of five experts, including subject matter experts, digital media specialists, and biology practitioners, using a structured Likert-scale instrument. Data were collected through surveys, interviews, and validation questionnaires. The data were analyzed using the Content Validity Ratio (CVR) and Content Validity Index (CVI). The validation results showed that the e-booklet achieved an average CVI value of 1.00, exceeding the critical CVR value of 0.99 from the five validators, indicating strong content validity. The e-booklet integrates various multimedia elements, including relevant texts, images, and videos, to enhance students' engagement and understanding of biological concepts. The high validity score indicates that the developed e-booklet is feasible for use as a biology learning medium, particularly for teaching the classification of living organisms. These findings demonstrate that the developed digital learning medium is highly feasible and suitable for supporting classroom instruction and independent student learning, aligning with the demands of 21st-century science education.

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Introduction

The success of learning can be determined by the teachers ability to implement innovations that involve students playing an active role (Carrión-Martínez et al., 2020). Professional teachers not only have the ability to prepare learning materials, but can also demonstrate creativity in the use and development of learning media (Hanifah et al., 2020). In this context, the development of information and communication technology opens up great opportunities for improving the quality of the learning process (Dewi, 2024; Ratheeswari, 2018). In fact, the 21st century learning paradigm explicitly requires teachers to integrate technology effectively without compromising pedagogical quality (Povitasari, 2023). The appropriate use of technology has been proven to create an effective, efficient, and engaging learning experience (Kouser & Majid, 2021). Therefore, the development of digital learning media needs to pay attention to three fundamental aspects, namely being innovative in responding to contemporary educational demands (Chaiyama & Kaewpila, 2022), applicative for ensures ease of implementation in various classroom conditions, and educative facilitates the achievement of predetermined to competency standard (Twiningasih & Gunarhadi, 2021).



The challenges of learning in the modern 21st century era require every teachers to be the main driver in building a culture of literacy, shaping a resilient personality, and developing learning potential that is relevant to the times (Padmadewi et al., 2018; Singh, 2019). Scientific literacy is one of the six essential skills needed in 21st century learning. *Programme for International Student Assessment* (PISA) 2018, defining scientific literacy as the ability of students to engage with science related issues and scientific ideas as reflective citizens (Guerrero & Sjöström, 2025). If science materials and learning are facilitated with the integration of appropriate competencies, students scientific literacy will be able improve (Istyadji & Sauqina, 2023; Yao & Guo, 2018). Biology learning in high school students is an important component of scientific literacy development. Biology education is contextual, requiring reasoning and analytical skills (Harahap et al., 2023). One of the fundamental topics in 10th grade biology is the the classification of living organisms. The learning objectives in the independent curriculum include identifying the benefits and basis of classifying living organisms, stating the taxonomy order of animals and plants, understanding the scientific naming system, understanding the development classification systems, and constructing cladograms (Maryoto, 2022). Material on the classification of living organisms is often considered difficult and challenging for students because the many unfamiliar scientific terms, extensive memorization requirements, inadequate availability of informative learning media (Bunayah, 2025; Az-zahra et al., 2023).

Based on initial observations conducted in three high schools, namely one in Pontianak City, one in Mempawah Regency, and another in Sambas Regency. Biology teachers often rely on lectures and discussion methods supported by presentations using PowerPoint and educational videos from YouTube. Diagnostic feedback revealed that fewer than 60% of students achieved passing marks on classification topics, highlighting low baseline comprehension. Therefore, there is a need for more interactive learning media that can integrates images and videos relevantly with comprehensive the materials, because this is material important component in improving science literacy. Students also expressed difficulties in understanding the concepts of classification living organisms independently, indicating a gap in the available independent resources and obstacles in learning media. The use of inappropriate learning media will significantly reduce scientific literacy skills and collaborative abilities (Mugabekazi et al., 2025; Zhao et al., 2025). Less interactive media results to a lack student engagement in discussions, analysis, and evaluation because the presentation of the material is one way and does not provides space for interactivity (Carrión-Martínez et al., 2020; Han et al., 2025).

Digital learning media, particularly electronic booklet have emerged as a promising solution to overcome this challenges. E-booklet combine the advantages of conventional booklet with digital technology, offering portability, multimedia integration, and environmental sustainability (Febriani et al., 2023). E-booklet are electronic book containing learning materials presented in a concise format with attractive and systematic layout, complete with relevant images and videos that can facilitate student understanding (Ayunda & Lufri, 2024). Previous research has shown the effectiveness of e-booklet in various biology topics (Hoiroh & Isnawati, 2020; Devi et al., 2021; Sarip et al., 2022; Marcellina et al., 2023; Oktaviani et al., 2024; Bunayah, 2025), the comparative study on the effectiveness e-booklet relative to other learning media can identify their specific advantages and optimal implementation conditions. This is due to the fact that prior research still lacks a specific focus on the focus on classification of living organisms to enhancing improving scientific literacy based on PISA indicators.



This study was conducted to address the identified gap by developing an e-booklet learning media designed for the topic classification of living organisms in 10th grade high school students. This study aims to develop and validate an e-booklet-based learning medium on the classification of living organisms to enhance scientific literacy among high school students. The novelty of this study lies in the integration of systematic multimedia elements aligned with scientific literacy competencies, presented in an accessible digital format to support independent and guided learning. The development of this e-booklet is expected to provide additional electronic learning media options for teachers and students, as well as inspire teachers to create and develop more varied and informative learning media.

Research Method

The study used Research and Development (R&D) method to build and validate a functional educational product (Arikunto, 2014; Gustiani, 2019). The development workflow adopted the Borg and Gall model, scaled to focus systematically on five foundational stages, with illustration of the stages represented in Figure 1: (1) Identifying potential and problems, (2) Data collection, (3) Product design, (4) Design validation, and (5) Design revision (Waruwu, 2024; Purba, 2024).

Stage 1: Identifying Potential and Problems

Preliminary study was conducted through interviews with three biology teachers and based on relevant information from a literature review. The interviews results showed that teaching of the material classification of living organism still relies on lectures, discussions, PowerPoint presentations, and educational videos from YouTube. The identified problems include the limited availability of interactive digital media, students difficulties in understand scientific terminology and concepts in taxonomy, the lack of multimedia based independent learning resources, existing media being considered uninformative and uninteresting.

Stage 2: Data Collection

Data collection includes analysis of the independent curriculum standard for 10th grade biology learning, content on the material classification of living organisms, review of the available learning resources, identification of students learning needs through teachers interviews and analysis of supporting documents such as teaching modules.

Stage 3: Product Design

The e-booklet was designed using Canva and Flip PDF Professional software. The design process included storyboard preparation, content development based on a three dimensional scientific literacy framework (process, content, and scientific context), multimedia integration such as images, diagrams, video links, quick response codes, interactive elements. The e-booklet is designed to be accessible on various devices with an optimal file size.

Stage 4: Design Validation

Expert validation was carried out using a Likert scale (1-4) assessment questionnaire consisting of 20 items, covering four aspects: format (5 items), content (8 items), language (4 items), and practicality (3 items). Each validator (two biology subject matter experts, one digital learning media experts, and two experienced teacher practitioner) to assessed the e-booklet independently and provided quantitative assessments and qualitative feedback.

Stage 5: Design Revision

Based on validator feedback, for the e-booklet refinement stage revisions include improving image resolution and clarity in diagrams, adding examples and expanding the



discussion of the presented content, to developing a glossary and ensuring consistency in terminology, as well as enhancing navigation features such as page hide and search functions.

Instrument for validation in this study are based on the assessment criteria for digital learning media that have been established, adapted from previous study on the validation of e-booklet media (Fitriani & Fitrihidajati, 2023; Hoiroh & Isnawati, 2020). The validation questionnaire uses a Likert scale assessment with four main aspects as explained in the procedure section. This instrument was validated to assess content validity by experts in educational research methodology before implementation to ensure that all items can accurately measure the relevant constructs. Quantitative content validity was determined using Lawshe's Content Validity Ratio (CVR) and Content Validity Index (CVI) formulas (Lawshe, 1975). The CVR for each item was calculated as follows: $CVR = \frac{n_e - N/2}{N/2}$. Where n_e represents the number of validators rating an item as essential, and N represents the total number of panel validators ($N = 5$). The critical CVR threshold for five validators at a significance level of $\alpha = 0.05$ is 0.99. The comprehensive Content Validity Index was derived from the average of the computed valid item ratios:

$$CVI = \frac{\sum CVR_{valid}}{n_{items}}$$

The validity category is determined based on the CVI value (Arikunto, 2014), where a value of 0.80-1.00 is considered Very Valid (Highly Eligible), a value of 0.60-0.79 is considered Valid (Eligible), a value of 0.40-0.59 is considered Fairly Valid (Need Revision), and a value of 0.00-0.39 is considered Invalid (Not Eligible).

Results and Discussion

The development of the e-booklet on the classification of living organisms follows five systematic stages based on modified Borg and Gall model. Each stage significantly influences the elements of final product, ensuring alignment with curriculum standard, pedagogical best practices, and the framework of scientific literacy.

Stage 1: Identify the Problem

Based on previous study several main challenges in learning the classification of organism have been revealed: (1) students difficulty in memorizing scientific terms and taxonomy hierarchies, with teachers reporting that students often struggle to remember taxonomy levels and Latin names, (2) the availability of interactive learning resources beyond textbooks and one way PowerPoint, (3) inadequate multimedia integration in the materials on the classification of living organisms, with most resources relying on text based explanations, and (4) the lack of resources that support independent student learning outside of class. These findings are in line with previous study indicating that this material requires multimedia to improve understanding more effectively (Maryoto, 2022; Az-zahra et al., 2023).

Stage 2: Data Collection and Analysis

Analysis of the independent curriculum for grade 10th biology learning by identifying learning objectives. The curriculum emphasizes that students must be able to identify the benefits and basis of classification, explain the taxonomy system of animals and plants, apply the principles of scientific naming, understanding the development of classification systems, and be able to construct simple cladograms to represent evolutionary relationships. Content analysis reveals the need for a systematic presentation that progresses from basic concepts to advanced applications such as constructing phylogenetic trees and understanding the relationships of evolutionary processes in living organisms.

Stage 3: Product Design and Development

The developed e-booklet is designed to integrate several pedagogical principles that align with constructivist learning theory and the framework of scientific literacy namely:

- 1) Content Organization; The material is organized into six sections:
 - (1) Introduction to classification explains the importance and historical development of classification, (2) Basics and benefits of classification details the methods of classification, (3) Taxonomy hierarchies presents the seven taxonomy levels from kingdom to species, (4) Binomial nomenclature explains the rules of scientific naming, (5) Development of Classification systems traces the evolution of classification from Aristotels to modern times, (6) Phylogenetic relationships and cladograms introduce modern cladogram methods. Each part includes essential content information with explanatory text, and practice questions to strengthen understanding.
- 2) Multimedia Integration; The e-booklet integrates various multimedia elements, including:
 - (1) High quality images showing a variety of living organisms, (2) Detailed diagrams taxonomy hierarchies and cladograms, (3) Links to educational videos examining specimens to identify of living organisms, and using identification keys for animals and plants, (4) Interactive navigation features that enable non-linear learning through table of contents, page hide and search features, (5) QR codes links to supplementary virtual learning resources.
- 3) Scientific Literacy Framework; Content presentation aligns with the three dimensions of scientific literacy identified by PISA (Shaffer et al., 2019):
 - (1) Scientific process, activities and questions that require students to identify classification criteria, explain the classification system, use scientific evidence in the classification system (analyzing morphological, anatomical, genetic data, and evolutionary), (2) Scientific content, comprehensive coverage of taxonomy and binomial nomenclature concept and evolutionary relationship processes (3) Scientific context, application of classification knowledge to solve problems.
- 4) Visual Design; The e-booklet used visual design principles consistent with clear typography and readable font sizes (minimum 11pt for body text, larger for titles and subtitles), suitable color scheme to enhances visuals and increases readability, balanced layout, simplified infographics, visual representations, symbols for intuitive navigation. The developed e-booklet comprised 28 pages presenting content and integrated with multimedia (images, diagrams, video links, QR codes). Several displays of the developed e-booklet are presented in Figure 2.

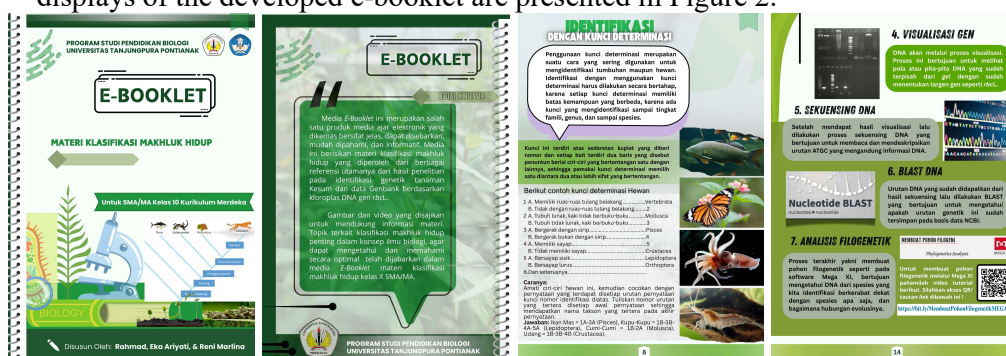


Figure 1. Representative Displays of the Developed E-Booklet

**Stage 4: Validation Result**

This validation process involves a comprehensive assessment by five expert validators by evaluating four main aspects: (1) Format, (2) Content, (3) Language, and (4) Practicality in the e-booklet. Table 1 the results of the validation assessment for each aspect and items.

Table 1. Summary of Expert Validation Results

Validation Aspect	Number of Items	Mean Score	CVR	CVI	Category
Format	5	3.80	1.00	1.00	Very Valid
Content	8	3.75	1.00	1.00	Very Valid
Language	4	3.90	1.00	1.00	Very Valid
Practicality	3	3.85	1.00	1.00	Very Valid
Overall Performance	20	3.81	1.00	1.00	Very Valid

The validation results show that the content validity with an overall CVI of 1.00 significantly exceeded the critical CVR value of 0.99 for five validators, with this the consensus of the validator concluded the e-booklet has met quality standard in all aspect. The obtained mean score of 3.81 out of 4.00 confirms the high quality and feasibility of the developed e-booklet as an learning media product.

1) Format (Mean Score = 3.80 and CVI = 1.00)

The validators rated the format aspect as excellent. Specific assessments identified include a layout design that is consistent with a clear-visual hierarchies, appropriate color scheme that enhanced readability without causing visual fatigue, a well navigation system that facilitated easy movement between sections, effective integration of visual elements that supported the textual content, as well as a responsive design adaptable to various devices. Validator feedback includes: "The layout is very attractive and professional. Colour usage is appropriate and not excessive" (Validator 1; Media Expert), "Intuitive navigation can make it easier for students to find specific topics" (Validator 2; Media Expert), and "The modern design will attract interest of students" (Validator 5; Biology Teacher). Suggested for improvement include adjusting some image resolutions to achieve an optimal display.

2) Content (Mean Score = 3.75 and CVI = 1.00)

The content aspect received a high validation score, indicating strong alignment with curriculum standard and pedagogical principles. The validators stated that the content coverage was comprehensive of all required topics as specified in the independent curriculum, it offered accurate and up-to-date scientific information consistent with current biological knowledge, demonstrated an effective use of examples and case studies from a variety of living organisms, and integrated contemporary taxonomic approaches, including molecular and phylogenetic classifications. The content also showed strong alignment with the dimensions of scientific literacy through its embedded questions and activities. This was supported by qualitative feedback from the experts; for instance, one evaluator noted, 'The material is well organized and develops logically from simple to complex concepts' (Validator 5; Biology Teacher). Suggested for additions including more diverse examples of taxonomy classification across various kingdoms and expanding the discussion on the prokaryotic classification system.

3) Language (Mean Score = 3.90 and CVI = 1.00)

The language aspect received a high validation score, with validators rating it exceptionally well across all criteria: clear and straightforward language, the use of accurate scientific paired terminology with adequate explanations and well-structured



sentences that facilitate understanding while reducing students cognitive load, consistent terminology to avoid confusion and the right balance between formal academic language and explanations that are easy for 10th grade students. Validator feedback includes: "The language is very clear and appropriate for the audience, and scientific terms are well explained" (Validator 1; Media Expert), "The sentence structure is already good, making complex concepts accessible" (Validator 3; Content Expert), and "Students will be able to understand this material independently because of the clear and straightforward use of language" (Validator 5; Biology Teacher). Suggested for addition a dedicated glossary section with definitions of scientific terms for quick reference to enhance interactive learning.

4) Practicality (Mean Score = 3.85 and CVI = 1.00)

The validators confirmed the practical applicability of the e-booklet with excellent criteria, equipped with easy navigation for users who require minimal technical skills, flexible access across various devices and platforms, efficient learning resources that can support classroom teaching and independent learning, clear instructions for accessing multimedia elements that reduce technical barriers, and optimal file size (around 15-20 MB) that makes it easy to download and share via email or cloud storage in a short time with a moderate internet connection. Validator feedback includes: "This e-booklet is very practical to use in learning activities for 10th grade students" (Validator 2; Media Expert), "The file size is highly appropriate, which supports ease of sharing with students. I can foresee this digital learning media being recommended for classroom instruction and utilized outside the classroom for students independent learning" (Validator 5; Biology Teacher).

Stage 5: Product Revision

Based on the validators feedback, several revisions were undertaken to improve the quality of the developed e-booklet on the classification of living organisms: (1) Content improvements included incorporating more diverse examples of taxonomic classification representing all kingdoms, discussion of prokaryotic classification, and providing additional practice questions designed to assess multiple cognitive levels. Real life applications are integrated studies such as used classification in biodiversity conservation and species identification in local environments, which can be practiced by students with living organism found in their school surroundings, thereby promoting authentic learning experiences (2) Visual Enhancement the image resolution was upgraded from standard to high definition, ensuring an optimal display across various screen sizes. The visual quality of the e-booklet was enhanced improving diagram clarity, increasing font readability, applying a consistent colour scheme, and file compression was optimized to reduce file size while preserving visual quality (3) Language refinement aimed to enhance readability through the use of clear and accessible language. In addition, a comprehensive glossary containing more than 30 scientific terms, along with clear definitions and relevant examples was developed (4) Functional improvements focused on enhancing usability by incorporating a bookmark structure for easy navigation across all sections. A search function was added to facilitate faster access to specific topics, while printable worksheets were provided to support offline learning without requiring computers, tablets, and smartphones.

Development of e-booklet learning media successfully addressed the gaps identified in resources for learning about the classification of living organisms. The validation results, which fell into the 'very valid' category (overall CVI = 1.00) indicate that the developed product meets strong quality standard across all aspects of format, content, language, and



practicality. These results exceed those reported in similar studies Hoiroh & Isnawati (2020) reported a validation percentage of 89.07% for the material and 92.21% for the media, whereas (Oktaviani et al. (2024) achieved 96.88% feasibility. Expert agreement states in this study that is very valid. The developed e-booklet is designed by integrating four essentials 21st century learning principles in modern education (Indarta et al., 2022; Kızılaslan, 2019). First, the communication aspect is realized through the integration of text, visuals, and multimedia to present complex biological concepts, accommodate diverse students learning preferences. Second, critical thinking is facilitated through questions and activities that encourage students to analyze, compare, and evaluate classification systems based on empirical scientific evidence. Third, creativity is fostered through intuitive navigation that allows students to personalize their exploration of material according to their individual interests and learning pace. Fourth, digital literacy is developed through the integration of digital tools and resources that prepare students for technology based academic and professional environments. By integrating of these four principles, the e-booklet transcends being a mere instructional media and learning resource, it evolves into a comprehensive learning environment that actively supports students' cognitive processes in alignment with contemporary educational goals (Chaiyama & Kaewpila, 2022).

The integration of scientific literacy dimensions throughout the e-booklet aligns with the objectives of contemporary biology education (Vieira & Tenreiro-Viera, 2016). The e-booklet explicitly addresses the scientific process (observation, classification, inference), scientific knowledge (taxonomy, evolutionary concepts), scientific context (biodiversity conservation, species identification). This integration facilitates the development of scientific literacy competencies that are essential for 21st-century education (Chaiyama & Kaewpila, 2022; Kızılaslan, 2019). Previous studies have demonstrated that science learning materials integrating scientific literacy competencies can significantly enhance students scientific literacy (Yao & Guo, 2018). Furthermore, the e-booklet presents biological classification not merely as a hierarchical system to be memorized but as a dynamic scientific process involving observation, evidence based evaluation, and scientific reasoning. This approach addresses a gap in that traditional science education, which often prioritizes content acquisition at the expense of scientific literacy development (Bellová et al., 2018; Carrión-Martínez et al., 2020).

According to cognitive theory of multimedia learning, individuals learn more effectively from words and pictures than from words alone (Sopanda et al., 2023). Images and diagrams provide visual representations of abstract concepts, making taxonomic hierarchies and evolutionary relationships more concrete, thereby supporting understanding. The videos demonstrate dynamic processes such as organism examination, classification procedures, while providing clear instructions for independent student practice, and interactive elements foster active learning through exploration and discovery activities, moving away from passive reading. This multimedia approach aligns with the principle that effective digital learning media must meet innovative, applicable, and educational aspects (Twiningasih & Gunarhadi, 2021). The experts' unanimous agreement on the quality of multimedia integration (Item 12, Average = 3.8, CVR = 1.00) provides empirical support for the effectiveness of the media design. The findings of this study are in line with and expand upon previous research regarding e-booklet development in biology education, in which Febriani et al. (2023) obtained a validity score of 96.81% for an e-booklet on the role of bacteria while Oktaviani et al. (2024) achieved a validity score of 96.88% for an e-booklet on



genetics. This study also produced high validity scores confirming that a systematic development process directly contributes to the quality of the resulting instructional product.

This study makes a distinct contribution to the development of biology learning media by addressing aspects that have received limited attention in previous studies. First, it explicitly integrated the framework of scientific literacy into the design and development of content, ensuring that learning activities address the three dimensions of scientific literacy identified by PISA (Shaffer et al., 2019). This differs from some previous e-booklet development studies focused on content delivery rather than the integration of scientific literacy competencies. Second, the integration of multimedia in this study is carried out comprehensive and systematic to multimedia integrated by combining various media formats, including images, diagrams, material video links, interactive elements, and QR codes, each aligned with specific learning objectives, thereby created a more interactive learning experience than that reported in several previous e-booklet development studies, that generally only integrated images (Hoiroh & Isnawati, 2020) or video (Devi et al., 2021). Third, from a methodology perspective, this study used the Content Validity Index based on Lawshe (1975) critical value as the basis for assessing validity, which offers a more systematic and transparent approach than the percentage-based method commonly reported in previous studies.

Practically the e-booklet media can be implemented in various learning settings. In independent learning, students can access the e-booklet anytime and anywhere through its navigation features, glossary, and multimedia elements, enabling them to explore the learning materials independently without relying solely on teacher guidance (Az-zahra et al., 2023). In the classroom environment, teachers can integrate e-booklet into various instructional strategies such as flipped classroom, blended learning, and differentiated learning, thereby supporting systematic planning while providing flexibility according to students' needs. From an assessment perspective, the practice questions in the e-booklet function as formative assessment tools that help teachers monitor students understanding while preparing students for summative assessments and digital format makes the e-booklet suitable for distance and hybrid learning. Despite achieving high validation results, this study is limited to the development and content validation stages without empirical evaluation of the e-booklet effectiveness, future studies should employ experimental or quasi-experimental designs to examine impact on students' achievement, learning motivation, and scientific literacy.

In addition, the validation involved only five experts from West Kalimantan and not include large scale field testing, future studies should involved teachers and students from different regions and school settings to improve the generalizability of the findings. Limited access to digital devices and internet connectivity, particularly in remote areas, should also be considered, development of an offline version or other accessible alternatives is recommended. The successful development and validation of the e-booklet have several important practical and policy implications. From a practical perspective, teachers should receive training not only in the use of digital learning media but also in instructional media development, graphic design, multimedia integration, and the creation of interactive learning content. From a policy perspective, government educational stakeholders must provide institutional support for the development of quality digital learning materials through funding, technical training or workshops. Furthermore, a scientific literacy framework needs to be established a standard for development of all science learning materials as reflected educational curriculum guidelines.



Conclusion

This study successfully developed an e-booklet on the classification of living organisms for 10th grade high school students through five stages of systematic development based on the modified Borg and Gall model. The validation results obtained a CVI score of 1.00, which exceeded the critical CVR value of 0.99, indicating that five validators were classified as very valid based on the assessment of all aspects, namely format, content, language, and practicality, declared very feasible for use as a biology learning media. This e-booklet integrated systematic content, multimedia, and a comprehensive of scientific literacy framework, thereby supporting independent learning while fostering essential 21st century competencies; critical thinking, communication, and digital literacy. These finding reinforce the evidence that effectiveness of a systematically developed e-booklet in biology education and scientific literacy framework can be systematically integrated into the design of digital learning media.

Recommendation

Future studies are recommended to empirically test the e-booklet effectiveness through experimental designs, larger scale feasibility test, and comprehensive impact assessments. Additionally, integrating the developed digital media into local Biology Subject Teacher Working Groups (MGMP Biologi) activities using of learning media in biology instruction.

References

- Arikunto, S. (2014). *Prosedur penelitian suatu pendekatan praktik (edisi ke-15)*. Semarang: PT Rineka Cipta.
- Ayunda, S. N., & Lufri, L. (2024). Meta-analysis: validity of developing e-booklets for high school biology learning. *Al-Jahiz: Journal of Biology Education Research*, 5(2), 152-163. <https://doi.org/10.32332/al-jahiz.v5i2.9664>
- Az-zahra, C. F., Kurnia, N., & Hamka, L. (2023). Pengembangan *booklet* sebagai penunjang sumber belajar biologi materi prinsip-prinsip klasifikasi makhluk hidup di SMA. *Seminar Nasional Hasil Penelitian 2023* (pp. 2236-2245). LP2M Universitas Negeri Makassar.
- Bellová, R., Melicherčíková, D., & Tomčík, P. (2018). Possible reasons for low scientific literacy of Slovak students in some natural science subjects. *Research in Science and Technological Education*, 36(2), 226-242. <https://doi.org/10.1080/02635143.2017.1367656>
- Bunayah, A. (2025). Pengembangan *e-booklet* klasifikasi makhluk hidup SMA kelas X melalui identifikasi bakteri pada ikan mas (*Cyprinus carpio*) keramba jaring apung di waduk koto panjang. *Begibung: Jurnal Penelitian Multidisiplin*, 3(3), 29-36. <https://doi.org/10.62667/begibung.v3i3.180>
- Carrión-Martínez, J. J., Luque-de la Rosa, A., Fernández-Cerero, J., & Montenegro-Rueda, M. (2020). Information and communications technologies (ICTs) in education for sustainable development: a bibliographic review. *Sustainability*, 12(8), 1-12. <https://doi.org/10.3390/SU12083288>
- Chaiyama, N., & Kaewpila, N. (2022). The development of life and career skills in 21st century test for undergraduate students. *European Journal of Educational Research*, 11(1), 51-68. <https://doi.org/10.12973/eu-jer.11.1.51>



- Devi, A. K., Noorhidayati, N., & Hardiansyah, H. (2021). Feasibility of e-booklet learning media on the concept of human reproductive system. *JPBIO: Jurnal Pendidikan Biologi*, 6(2), 262-271. <https://doi.org/10.31932/jpbio.v6i2.1404>
- Dewi, A. C. (2024). Peran teknologi dalam meningkatkan kualitas pembelajaran di era digital. *Jurnal Riset Guru Indonesia*, 3(3), 165-170. <https://doi.org/10.62388/jrgi.v3i3.473>
- Febriani, S., Yeni, L. F., & Wahyuni, E. S. (2023). Pengembangan *e-booklet* pada sub materi peranan bakteri kelas X SMA sebagai media pembelajaran. *Bioscientist: Jurnal Ilmiah Biologi*, 11(2), 1071-1083. <https://doi.org/10.33394/bioscientist.v11i2.8634>
- Fitriani, N. N., & Fitrihidajati, H. (2023). Development of waste recycling sub material e-booklet to train science literacy skill of X grades senior high school students. *Bioedu: Berkala Ilmiah Pendidikan Biologi*, 12(2), 403-413. <https://doi.org/10.26740/bioedu.v12n2.p403-413>
- Guerrero, G., & Sjöström, J. (2025). Critical scientific and environmental literacies: a systematic and critical review. *Studies in Science Education*, 61(1), 41-87. <https://doi.org/10.1080/03057267.2024.2344988>
- Gustiani, S. (2019). Research and development (R&D) method as a model design in educational research and its alternatives. *Holistics Journals*, 11(2), 12-22. <https://jurnal.polsri.ac.id/index.php/holistic>
- Han, W., Wang, T., Takizawa, Y., & Pill, S. (2025). Virtual reality as a mediating tool in addressing social communication disorder: current understanding and implementation strategies. *Languages*, 10(9), 226. <https://doi.org/10.3390/languages10090226>
- Hanifah, Afrikani, T., & Yani, I. (2020). Pengembangan media ajar *e-booklet* materi plantae untuk meningkatkan hasil belajar biologi siswa. *Journal of Biology Education Research*, 1(1), 10-16. <https://doi.org/10.55215/jber.v1i1.2631>
- Harahap, U. K., Selaras, G. H., & Ardi, A. (2023). Meta-analysis of the impact of problem-based learning on high school students critical thinking abilities in biology education. *Journal of Digital Learning and Education*, 3(2), 172-184. <https://doi.org/10.52562/jdle.v3i2.751>
- Hoiroh, A. M. M., & Isnawati. (2020). Pengembangan media *booklet* elektronik materi jamur untuk meningkatkan pemahaman konsep siswa kelas X SMA. *Bioedu: Berkala Ilmiah Pendidikan Biologi*, 9(1), 292-301. <https://doi.org/10.26740/bioedu.v9n2.p292-301>
- Indarta, Y., Jalinus, N., Waskito, W., Samala, A. D., Riyanda, A. R., & Adi, N. H. (2022). Relevansi kurikulum merdeka belajar dengan model pembelajaran abad 21 dalam perkembangan era society 5.0. *Edukatif: Jurnal Ilmu Pendidikan*, 4(2), 3011-3024. <https://doi.org/10.31004/edukatif.v4i2.2589>
- Istiyadji, M., & Sauqina. (2023). Conception of scientific literacy in the development of scientific literacy assessment tools: a systematic theoretical review. *Journal of Turkish Science Education*, 20(2), 281-308. <https://doi.org/10.36681/tused.2023.016>
- Kızılaslan, A. (2019). The development of science process skills in visually impaired students: analysis of the activities. *International Journal of Evaluation and Research in Education*, 8(1), 90-96. <https://doi.org/10.11591/ijere.v8i1.17427>
- Kouser, S., & Majid, I. (2021). Technological tools for enhancing teaching and learning process. *Towards Excellence*, 13(1), 366-373. <https://doi.org/10.37867/TE130133>



- Lawshe, C. H. (1975). A quantitative approach to content validity. *Personnel Psychology*, 28(4), 563-575. <https://doi.org/10.1111/j.1744-6570.1975.tb01393.x>
- Marcellina, R. J., Karyadi, B., Parlindungan, D., Uliyandari, M., & Sutarno, M. (2023). Pengembangan *e-booklet* lemea lebung sebagai media pembelajaran materi bioteknologi untuk siswa SMP. *Bioedusains: Jurnal Pendidikan Biologi dan Sains*, 6(1), 110-119. <https://doi.org/10.31539/bioedusains.v6i1.5923>
- Maryoto. (2022). *Implementasi model pembelajaran picture pada pembelajaran klasifikasi makhluk hidup*. Lombok: Pusat Pengembangan Pendidikan dan Penelitian Indonesia.
- Mugabekazi, J. C., Mukanziza, J., Nizeyimana, P., & Manirahari, P. (2025). Integrating collaborative learning strategies in the curriculum: enhancing critical thinking and communication skills in primary education. *European Journal of Education Studies*, 12(3), 14-38. <https://doi.org/10.46827/ejes.v12i3.5848>
- Nengsih, N. R., Yusmaita, E., & Gazali, F. (2019). Evaluasi validitas konten dan konstruk bahan ajar asam basa berbasis REACT. *EduKimia Journal*, 1(1), 1-10. <https://doi.org/10.24036/ekj.v1i1.104017>
- Oktaviani, R. O., Mardiyanningsih, A. N., & Candramila, W. (2024). Pengembangan media *e-booklet* gen, DNA, kromosom untuk kelas XII SMA. *Diklabio: Jurnal Pendidikan dan Pembelajaran Biologi*, 8(1), 76-88. <https://doi.org/10.33369/diklabio.8.1.76-88>
- Padmadewi, N. N., Artini, L. P., & Nitiasih, P. K. (2018). Techniques for building character and literacy for 21st century education. *International Conference on Education Innovation*, 13, 250-253. <https://doi.org/10.2991/icei-17.2018.65>
- Povitasari. (2023). Strategi integrasi teknologi pendidikan dalam pembelajaran abad 21 (studi kasus pada guru madrasah ibtidaiyah di Kabupaten Garut). *IDAROTUNA: Jurnal Administrative Science*, 4(2), 247–264. <https://doi.org/10.54471/idarotuna.v4i2>
- Purba, A. (2024). Bahan ajar bahasa Indonesia di perguruan tinggi berbasis kompetensi: Orientasi teks; penelitian dan pengembangan di Universitas Jambi melalui model Borg & Gall. *Jurnal Ilmu Kehidupan dan Sosial Pakistan (PJLSS)*, 22(2), 24355-24369. <https://doi.org/10.57239/pjlss-2024-22.2.001739>
- Ratheeswari, K. (2018). Information communication technology in education. *India Journal of Applied Advanced Research*, 1(3), 45-47. <https://doi.org/10.21839/jaar.2018.v3S1.169>
- Sarip, M., Amintarti, S., & Utami, N. H. (2022). Validitas dan keterbacaan media ajar *e-booklet* untuk siswa SMA/MA materi keanekaragaman hayati. *Jupeis: Jurnal Pendidikan dan Ilmu Sosial*, 1(1), 43-59. <https://doi.org/10.57218/jupeis.Vol1.Iss1.30>
- Shaffer, J. F., Ferguson, J., & Denaro, K. (2019). Use of the test of scientific literacy skills reveals that fundamental literacy is an important contributor to scientific literacy. *CBE Life Sciences Education*, 18(3), 1-10. <https://doi.org/10.1187/cbe.18-12-0238>
- Singh, B. (2019). Character education in the 21st century. *Journal of Social Studies (JSS)*, 15(1), 1-12. <https://doi.org/10.21831/jss.v15i1.25226>
- Sopanda, L., Susiaty, U. D., & Hartono. (2023). Desain media *e-booklet* terintegrasi video pembelajaran terhadap kemampuan berpikir kritis dalam materi relasi dan fungsi. *Jurrimipa: Jurnal Riset Rumpun Matematika dan Ilmu Pengetahuan Alam*, 2(1), 188-201. <https://doi.org/10.55606/jurrimipa.v2i1.778>



- Twiningsih, A., & Gunarhadi. (2021). Model desain penyelenggaraan pendidikan inklusif. *Edudikara: Jurnal Pendidikan dan Pembelajaran*, 6(3), 272-277. <https://doi.org/10.32585/edudikara.v6i4.261>
- Vieira, R. M., Tenreiro-Vieira, C. (2016). Fostering scientific literacy and critical thinking in elementary science education. *International Journal of Science and Mathematics Education*, 14, 659-680. <https://doi.org/10.1007/s10763-014-9605-2>
- Waruwu, M. (2024). Metode penelitian dan pengembangan (R&D): konsep, jenis, tahapan dan kelebihan. *Jurnal Ilmiah Profesi Pendidikan*, 9(2), 1220-1230. <https://doi.org/10.29303/jipp.v9i2.2141>
- Yao, J., & Guo, Y. (2018). Core competences and scientific literacy: the recent reform of the school science curriculum in China. *International Journal of Science Education*, 40(15), 1913-1933. <https://doi.org/10.1080/09500693.2018.1514544>
- Zhao, X., Attapaiboon, T., & Jantharajit, N. (2025). Innovative integration of situated and collaborative learning: enhancing third-grade students' Chinese reading comprehension and social abilities. *Asian Journal of Contemporary Education*, 9(1), 27-41. <https://doi.org/10.55493/5052.v9i1.5302>