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Digital Herbarium for Biodiversity Learning: Integration of School Plant Inventory into Biology Learning Media

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ABSTRACT

A digital herbarium is a herbarium that has been digitized using technology to convert information from conventional data into digital form. This research study uses the concept of a digital herbarium based on real photos from school plant inventories and equipped with metadata on scientific names and morphological characteristics integrated in the form of a website. The purpose of this study is to develop technology-based learning media to improve students' understanding of abstract concepts of biodiversity. This study was conducted using an R&D method, with a one-group pretest-posttest design implemented during the product trial. The research instruments used multiple-choice comprehension test questions and expert validation sheets. The results of the study obtained the final form of the website containing 21 plant species from 17 families. The digital herbarium website learning media is classified as highly valid based on expert media validation results of 88%, subject matter expert validation of 96%, and student response of 84%. Based on expert validation, the developed product was declared valid for use in learning. In addition, the t-test analysis showed a significant difference between pretest and posttest scores ($p = 0.001 < 0.05$), which indicates the effectiveness of the product in enhancing students' learning outcomes. The results indicate that the digital herbarium website learning media effectively improved students' understanding of biodiversity material, with an N-Gain score of 0.63 in the moderate category. Based on the results of the study, the digital herbarium website learning media was valid and effective in improving students' understanding of biodiversity material in biology learning.

Keyword: Biodiversity, digital herbarium, media, technology, website

INTRODUCTION

Twenty-first century education requires students to possess critical, creative, collaborative, and communicative thinking skills that are aligned with the rapid development of technology. Therefore learning innovation is needed, one of which is through the utilization of educational technology (Banarsari et al, 2023). In contemporary education, biology learning emphasizes student-centered approaches supported by innovative and contextual digital learning media to enhance students' engagement and conceptual understanding. Meanwhile, technology-based and contextual visual media can support students' understanding of biodiversity material through more interactive and meaningful learning experiences (Hastuti et al., 2025). One of the topics that requires direct learning

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experiences and high observational skills is biodiversity, as it is closely related to the identification and classification of living organisms found in students' surrounding environments (Panula et al., 2018)

In practice, biodiversity learning in schools is often delivered in a simple manner using textbooks and animated images (Stahl et al., 2020).This approach makes it difficult for students to understand the concept of species diversity around them because the learning process is not connected to real-life experiences encountered in their daily lives. This is in line with the study by Gonzalez (2023) which demonstrates how place-based education—linking learning to real places—can improve cognitive and emotional aspects related to environmental topics. In other words, learning that does not relate to everyday experiences can reduce the effectiveness of students' understanding. In addition, school environments have diverse learning resources, such as various plant species that can be used as direct objects for learning biodiversity. Unfortunately, this local potential has not been optimally utilized as learning material (Harahap et al., 2024).

Based on the results of a preliminary study conducted through the distribution of questionnaires to eight biology teachers at senior high schools (SMA/MA/equivalent) in Surabaya, it was found that 62.5% of teachers stated that biodiversity material requires more contextual learning media, 87.5% indicated that school plant inventory can be utilized as a source of biology learning, and 87.5% agreed that students would more easily understand the material through real examples in the school environment. In terms of digitalization, 75% of teachers stated that the use of digital-based media can increase students' learning interest and is in accordance with current learning needs. Therefore, digital herbarium learning media is one of the efforts that can be developed to overcome these limitations.

A digital herbarium is a modern form of a conventional herbarium that utilizes digital technology to present collections of plant specimens in an interactive manner(Andika et al., 2024). Through this medium, students can recognize, observe, and study the characteristics of various plant species in the school environment without directly interacting with fragile physical samples, such as conventional herbariums that require special maintenance, large storage spaces, and are not always accessible (Hanifah et al., 2025). Digital herbarium media also allows the presentation of high-resolution images, morphological descriptions, and scientific classification of each species.

According to Setiawan (2022), introducing students to biodiversity in their surrounding environment can enhance their awareness of the importance of environmental conservation and biodiversity preservation. Thus, this learning media is expected to enhance students' understanding of biodiversity concepts through engaging, interactive, and environment-based learning experiences (Nasution & Astuti, 2024). Therefore, research on the development of a digital herbarium learning medium based on school plant inventory is necessary to support students' conceptual understanding of biodiversity through contextual and visually interactive learning experiences.

METHOD

Research Design

This study employed a Research and Development (R&D) approach. A one-group pretest–posttest design was used during the product testing stage to evaluate the effectiveness of the developed learning media. The study was conducted in an A-accredited

private senior high school in Surabaya, Indonesia. The development procedure followed the Borg and Gall model, which consists of nine stages: (1) identification of potential and problems, (2) data collection, (3) product design, (4) design validation, (5) design revision, (6) product testing, (7) product revision, (8) usage testing, and (9) final product revision.

The research data were obtained from feasibility and effectiveness tests of the developed digital herbarium learning media. The feasibility data were collected through expert validation questionnaires involving media experts and biology education experts to assess the suitability of the learning media. Meanwhile, the effectiveness data were obtained from pretest and posttest results administered during the implementation stage. The pretest was conducted prior to the use of the digital herbarium learning media to identify students' initial understanding, while the posttest was administered after the learning process to measure improvements in students' understanding of biodiversity concepts. The collected data were then analyzed to determine the feasibility and effectiveness of the developed learning media.

Participant

The research population consisted of students from an A-accredited private senior high school in Surabaya, Indonesia. The research sample comprised 35 students from class X Phase E-4 who had completed the biodiversity learning material. The participants were selected using purposive sampling because the class had already studied biodiversity material and was therefore considered appropriate for evaluating the effectiveness of the developed digital herbarium learning media.

Instruments

The instruments used in this study consisted of treatment instruments and measurement instruments. The digital herbarium was designed based on plant inventory data collected from the school environment and developed as a digital learning resource for biodiversity topics. The development of the learning media was guided by principles of digital learning media development and contextual learning, referring to the Research and Development framework proposed by Borg and Gall. To ensure the quality and feasibility of the digital herbarium website, the media was validated by media experts and subject-matter experts using validation sheets. The validation instruments were developed based on established criteria for learning media evaluation, covering aspects of content feasibility, presentation, and visual appearance. The validation process aimed to ensure the accuracy of the biological content, clarity of information presentation, and the effectiveness of the media design. The results of expert validation were used as the basis for revising the media until it was deemed appropriate for instructional use.

The measurement instrument was used to assess the research variable. The dependent variable in this study was students' understanding of biodiversity concepts. The measurement instrument consisted of a biodiversity concept understanding test covering several indicators, including identifying levels of biodiversity, classifying biodiversity based on observable characteristics, explaining the benefits of biodiversity, and analyzing biodiversity conservation efforts. The test was administered in the form of pretest and post-test to measure changes in students' conceptual understanding before and after the implementation of the digital herbarium learning media. The validity of the test instrument was established through expert judgment by subject-matter experts to ensure alignment

between test items, learning objectives, and indicators of conceptual understanding.

Data Analysis

This study employed quantitative data in the form of students' pretest and post test scores on biodiversity concept understanding. Data were collected during the usage testing stage using a validated biodiversity concept understanding test administered before and after the implementation of the digital herbarium learning media.

Data analysis included a normality test as a prerequisite, followed by a paired-sample *t*-test to examine differences in students' understanding before and after the intervention. In addition, normalized gain (*N-gain*) analysis was used to determine the effectiveness of the digital herbarium learning media in improving students' understanding of biodiversity concepts.

RESULTS AND DISCUSSION

Results

The results showed that 21 plants were recorded during the exploration. The plants obtained are presented in Table 1.

Table 1. Plant Data

No.	Plant
1.	Asoka merah *(Ixora coccinea)*
2.	Adam hawa *(Tradescantia spathacea)*
3.	Sawo *(Manilkara zapota)*
4.	Ginseng jawa *(Duranta erecta)*
5.	Pucuk merah *(Syzygium myrtifolium)*
6.	Kamboja jepang *(Adenium obesum)*
7.	Kembang sepatu *(Hibiscus rosa-sinensis)*
8.	Bunga kertas *(Bougainvillea spectabilis)*
9.	Jarak merah *(Jatropha multifida)*
10.	Kembang gading *(Tabernaemontana divaricata)*
11.	Pepaya *(Carica papaya)*
12.	Bayam merah *(Alternanthera brasiliana)*
13.	Nangka *(Artocarpus heterophyllus)*
14.	Kamboja hati *(Plumeria obtusa)*
15.	Kayu putih *(Melaleuca quinquenervia)*
16.	Lengkuas *(Alpinia galanga)*
17.	Jeruk nipis *(Citrus aurantiifolia)*
18.	Delima *(Punica granatum)*
19.	Cocor bebek *(Kalanchoe laetivirens)*
20.	Lili pita merah *(Dracaena reflexa* var. *angustifolia)*
21.	Lidah mertua *(Dracaena trifasciata)*

Based on the results of the plant inventory, a digital herbarium website was developed as the final product of this research. The plant inventory data were used as the main content of the media, which was systematically organized and presented in digital form to support

biodiversity learning. The digital herbarium website contains information on each plant species, including local and scientific names, morphological descriptions, and taxonomic classification accompanied by visual documentation. The media was designed with an interactive and user-friendly interface, allowing students to observe and study plant diversity in the school environment contextually without limitations of space and time. The final product of the digital herbarium website is shown in Figure 1, Figure 2, and Figure 3.

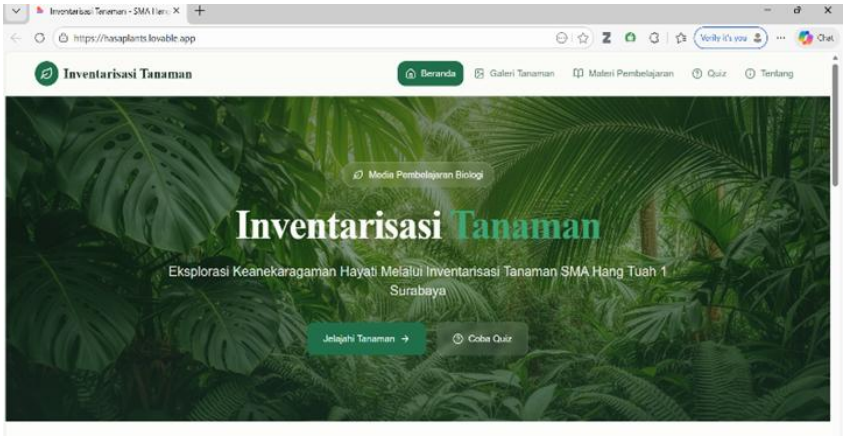

Figure 1. Website Homepage Display

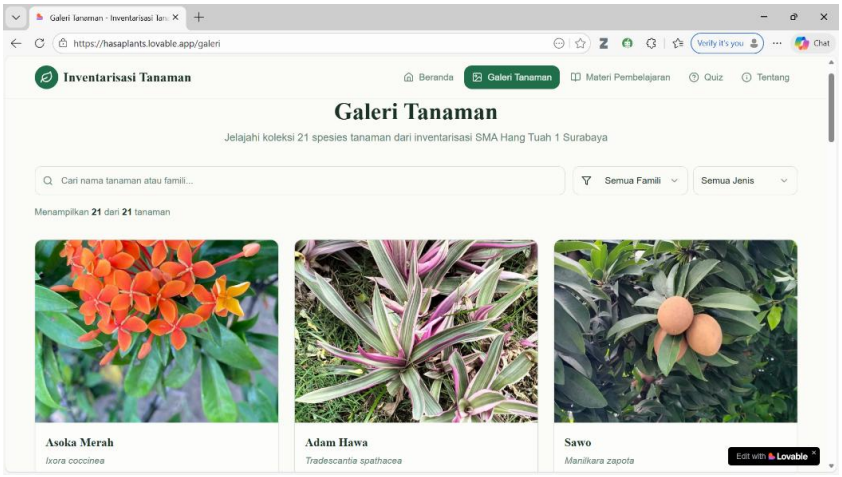

Figure 2. Plant Gallery Page Display

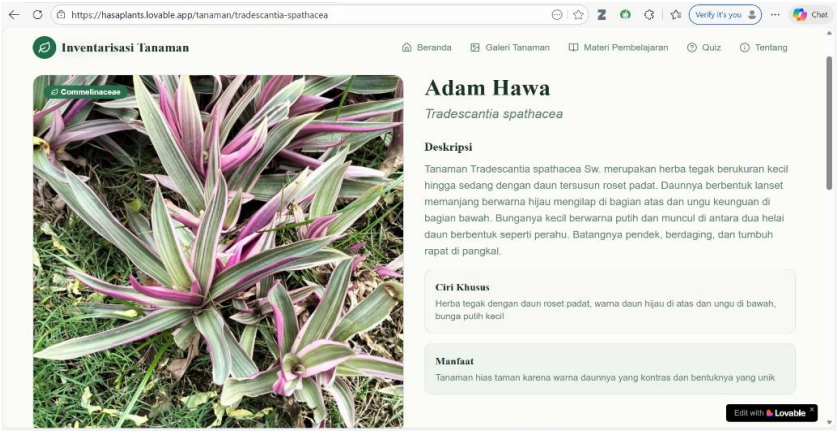

Figure 3. Plant Details Page Display

Media validation was conducted by two learning media experts to assess the feasibility of the developed digital herbarium website. The data from the media experts' validation can be seen in Table 2.

Table 2. Media Expert Validation Score

Assessment Criteria	x	x^i1	x^i2	Percentage	Category
Quality Aspect					
The quality of the developed digital herbarium website meets the criteria.	10	5	4	90%	Very Valid
The interface design is attractive and interactive.	10	5	4	90%	Very Valid
Images and text are easy to read.	10	5	3	80%	Valid
The media can be used at various times and under different conditions.	10	5	4	90%	Very Valid
Media navigation is easy to understand.	10	5	4	90%	Very Valid
Total	50	25	19	88%	Very Valid
Technical Presentation					
Content layout is proportional and consistent.	10	5	4	90%	Very Valid
The media is easy to use, operate, and does not require much time to present.	10	5	4	90%	Very Valid
The media can be accessed on various devices.	10	5	5	100%	Very Valid
Instructions for product use are clearly presented.	10	5	3	80%	Valid
Total	40	20	16	90%	Very Valid
Overall Total	90	45	35	88%	Very Valid

Notes:
x : total possible score
x^i1: total score from validator 1
x^i2: total score from validator 2

The results of the media expert validation show that the digital herbarium website learning media that was developed obtained a high percentage in two main assessment aspects, namely the quality aspect (88%) and the technical presentation aspect (90%). These results indicate that the media that was developed has met the criteria of being very suitable for use in learning. The material validation was conducted by two subject-matter experts to assess the suitability, completeness, and accuracy of the learning content presented in the digital herbarium website. The results of the material experts' validation are presented in Table 3.

Based on the results of subject matter expert validation in Table 3, it can be concluded that a score of 76 out of a total score of 95% was obtained for the content aspect of the learning media, and a score of 40 out of a total score of 100% was obtained for the language aspect. These results indicate that the digital herbarium website learning media has content and language that are very suitable for use as learning media in the classroom.

The data from the validation of multiple-choice questions used as pre-test and post-test questions was obtained from the results of a data analysis questionnaire filled out by two validators. The data from the subject matter experts' validation of the multiple-choice

questions can be seen in Table 4.

Based on the results of the multiple-choice question validation, a total score of 96 out of a total possible score of 100 was obtained, resulting in a percentage of 96% in the highly acceptable category. The validated multiple-choice questions can be used as pre-test and post-test questions in accordance with the specified material. Data normality testing aims to detect the distribution of data in a variable that will be used in the study. Data can be considered valid as proof of a research model if it is normally distributed. If the significance value is > 0.05, the data is considered normally distributed. The results of the normality test can be seen in Table 5.

Table 3. Material Expert Validation Score

Assessment Criteria	x	x^i1	x^i2	**Percentage**	**Category**
Content Aspect					
Alignment of the material with the learning outcomes.	10	5	5	100%	Very Valid
The material presented on the digital herbarium website is relevant to the learning objectives.	10	4	5	90%	Valid
The material presented on the digital herbarium website is clearly explained.	10	4	4	80%	Valid
The material presented is easy to understand.	10	5	5	100%	Very Valid
The material presented is in accordance with current developments.	10	5	5	100%	Very Valid
The material presented encourages students' curiosity.	10	5	5	100%	Very Valid
Plant examples are relevant to the school environment.	10	5	5	100%	Very Valid
Information about each plant is accurate.	10	4	5	90%	Valid
Total	80	37	39	95%	Very Valid
Language Aspect					
The language used is clear and easy to understand.	10	5	5	100%	Very Valid
The language used is appropriate to the cognitive level of Grade X senior high school students.	10	5	5	100%	Very Valid
The language used does not include local or regional dialects.	10	5	5	100%	Very Valid
The language used complies with standard Indonesian language conventions.	10	5	5	100%	Very Valid
Total	40	20	20	100%	Very Valid
Overall total	120	57	59	96%	Very Valid

Table 4. Multiple Choice Question Validation Score

Assessment Criteria	x	x^i1	x^i2	Percentage	Category
Material Aspect					
The test items are aligned with the competencies being measured.	10	5	5	100%	Very Valid
The answer options are homogeneous and logically constructed in terms of content.	10	5	4	90%	Valid
Clarity of the instructions for completing the test.	10	5	5	100%	Valid
The question stems are formulated concisely, clearly, and precisely.	10	4	5	90%	Very Valid
Images, graphs, tables, or similar elements are clear and function effectively.	10	5	4	90%	Very Valid
Each test item contains a single complete idea.	10	4	5	90%	Very Valid
Total	60	28	28	93%	Very Valid
Language Aspect					
The language used is clear and easy to understand.	10	5	5	100%	Very Valid
The wording does not contain ambiguous or double meanings.	10	5	5	100%	Very Valid
Does not use local or regional language.	10	5	5	100%	Very Valid
The language used complies with standard Indonesian language conventions.	10	5	5	100%	Very Valid
Total	40	20	20	100%	Very Valid
Overall total	100	48	48	96%	Very Valid

Table 5. Normality Test

	Statistic	df	Sig.	Statistic	df	Sig.
selisih	.107	35	.200*	.953	35	.136

Based on the SPSS calculation results in Table 5, it can be seen that the Sig value of 0.136 > 0.05, so it can be concluded that the data is normally distributed. Data analysis was conducted to test the significance of the accurate product usage test results. Researchers used the t-test (Paired Sample T-test) with SPSS 27 software. The basis for the Paired Sample Test decision is as follows. If the Sig. (2-tailed) value is < 0.05, then there is a significant difference between the learning outcomes in the pre-test and post-test data, and if the Sig. (2-tailed) value is > 0.05, then there is no significant difference between the learning outcomes in the pre-test and post-test data. The t-test results can be seen in Table 6.

Table 6. T-Test Results

	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)
Pair 1 pretest-posttest	-30.28571	20.07130	3.39267	-8.927	34	<,001

Based on the results obtained in Table 6 using SPSS 27 software, a sig value of .001 was obtained, which means that sig 0.001 < 0.05, so it is considered that there is a significant difference between student learning outcomes before using the digital herbarium website and after using the digital herbarium website. This shows that the digital herbarium website is effective for use in the classroom learning process. The next data analysis technique is the N-Gain (Normalized Gain) test to determine the level of improvement in student learning outcomes after being given treatment by comparing pre-test and post-test scores. The results of the N-Gain test are presented in Table 7.

Table 7. N-Gain Test Results

	N	Minimum	Maximum	Mean	Std. Deviation
NGain	35	.00	1.00	.6337	.26305
Valid N (listwise)	35				

Based on the N-Gain calculation results of the students' pre-test and post-test scores, the average N-Gain score was 0.63, which falls into the moderate category. These results indicate that the use of digital herbarium website learning media can improve students' understanding of biodiversity material.

Discussion

The developed digital herbarium website is considered highly suitable for use as a learning medium. Validation by media experts shows that the media meets innovative and interactive criteria, including display design, feature and navigation completeness, and ease of accessibility on all devices. Clear navigation and consistency, such as easily recognizable features and icons, facilitate independent exploration by students (Yulando et al., 2019). In line with this, recent research on web-based learning media has shown that the use of online learning platforms significantly improves students' engagement and concept understanding in science subjects, supporting the effectiveness of website-based media in educational settings. A study by Nurfatah (2025) found that web-based learning media improved conceptual understanding and student participation, especially in science learning contexts where visual and interactive elements facilitate comprehension. In addition, technology-based learning media also has a learning effect by increasing learning independence and the quality of the learning experience (Elmunsyah et al., 2019). Meanwhile, expert assessment of the material shows that the content and presentation of the material, as well as the language used, are in line with the learning competencies in the subject of biodiversity. The material presented in the media is systematic and easy to understand, reinforcing that well-structured digital content can be more effective than conventional textbooks when appropriately aligned with learning goals. In support of this, research in basic education contexts demonstrates that technology-rich media can significantly enhance students' conceptual learning when the materials are relevant, structured, and presented in ways that align with learners' cognitive levels (Masriani, 2025).

Technology-based learning media can support students' conceptual understanding through interactive and visual learning experiences (Permana et al., 2024). The moderate improvement in students' conceptual understanding of biodiversity may be influenced by several features of the developed digital herbarium website. The media provides real plant visuals and contextual examples derived from the school environment, enabling students to

observe biodiversity concepts more concretely. This visual and contextual presentation helps students identify, classify, and distinguish various plant species more easily, thereby supporting their understanding of biodiversity material. In addition, the website-based format allows students to access learning materials interactively and independently, which may enhance their engagement in the learning process. The integration of images, plant descriptions, and classification information also supports students in connecting abstract biological concepts with real-life examples found in their surroundings. Contextual learning is considered effective in improving conceptual understanding because students can relate learning material to their everyday experiences (Kolo, 2024). These findings are consistent with previous studies showing that website-based learning media can improve students' conceptual understanding and cognitive learning outcomes in biology learning, particularly in materials requiring visualization and observation (Saprudin & Pratama, 2025).

Digital media integrating contextual and local content can facilitate students' understanding of biodiversity material by connecting learning concepts with real examples found in their environment (Nenabu, 2025). Furthermore, advanced digital herbarium tools that incorporate augmented reality have been validated as effective for improving biodiversity literacy in higher education contexts, suggesting broad applicability of digital tools across education levels (Sari et al., 2025). Additional studies on digital plant projects and video podcast media highlight the potential of diverse digital resources in engaging learners and enhancing *plant awareness* and biodiversity understanding, reinforcing the value of varied digital media in biology education (Fitriani et al., 2025). Previous studies have reported that ICT-based and web-based learning environments can improve students' learning outcomes in biology, particularly in understanding biological concepts (Vekli, 2023). These findings collectively suggest that well-designed digital learning media, including websites, contribute significantly to improving student engagement, conceptual understanding, and digital literacy in science education contexts.

CONCLUSION.

Based on the results of the study, the digital herbarium website developed from the school plant inventory was considered Valid and effective as a biology learning medium. The use of the digital herbarium website was able to support students' conceptual understanding of biodiversity through contextual and interactive learning experiences. Therefore, the developed learning media can be utilized as an alternative digital learning resource in biodiversity learning.

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