



Validity of a Digital Poster-Based Laboratory Guide on the Effect of Coconut Water on *Aloe vera* Growth to Foster Students' Critical Thinking Skills

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ABSTRACT

Purpose of the study: The purpose of this study is to design a valid digital poster-based learning medium on the effects of coconut water on the growth of *Aloe vera* plants and to describe the validity of the designed digital poster-based learning.

Methodology: This study employed a Research and Development (R&D) approach using the 4D model (Define, Design, Develop, Disseminate), but was limited to the Develop stage. The study focused solely on the validity testing phase and did not include testing for practicality or effectiveness. The validation process involved three expert validators, comprising one biology lecturer and two biology teachers, selected through purposive sampling. Data were collected using a validation sheet that assessed content, presentation, language, and graphics. The collected data were analyzed descriptively using percentage-based validity criteria.

Main Findings: The digital poster-based laboratory guide on the effect of coconut water on the growth of *Aloe vera* was categorized as a highly valid resource, with an average validity score of 92.7%. The content aspect scored 93.3%, the organization 90.8%, the language 92.3%, and the graphics 94.4%. These findings indicate that the developed material is suitable for use as a biology learning resource.

Novelty/Originality of this study: The novelty of this study lies in the development of digital poster-based practical guidance learning materials that integrate local resources, specifically coconut water and *Aloe vera* plants, thereby not only presenting information visually but also guiding students towards hands-on activities designed to develop critical thinking skills.

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1. INTRODUCTION

The accelerating pace of change is driving significant transformations, particularly in education. In the Education 5.0 era, learning is no longer the same as it used to be; instead, it is evolving toward a more modern, active, and learner-centered 21st-century approach [1]. In the 21st century, teachers and students are expected to

develop creative and innovative learning by applying various instructional models that help students build and develop their own knowledge [2]-[4]. Education is no longer solely focused on mastering subject matter but is also expected to cultivate the higher-order thinking skills students need to address real-world challenges [5]-[7]. One of the main challenges in 21st-century education is mastering the 4C skills: Critical Thinking, Creativity, Collaboration, And Communication [8]-[10].

Among these four skills, critical thinking is particularly important because it helps students analyze information, evaluate data, solve problems, and draw logical conclusions [11]. In biology education, this skill is essential because students directly encounter natural phenomena that require observation, scientific reasoning, and empirical evidence. However, students' critical thinking skills remain relatively low because instruction still tends to focus on rote memorization and fails to engage students in the scientific process sufficiently [12]. In addition, the instructional media and laboratory learning activities used in schools are often still conventional and less able to facilitate students' active involvement in scientific inquiry.

Innovative learning materials can be developed in various forms, such as contextual textbooks, learning modules, student worksheets, and visual and digital media [13]. These materials serve as tools to present learning content in a way that is more engaging and easier for students to understand [14]-[16]. However, the use of learning media must be supported by appropriate learning methods and approaches [17]. Student-centered methods and approaches encourage active engagement, foster independent learning, and help students construct their own knowledge [18]. In addition to learning media and methods, learning resources also play a crucial role in supporting the learning process [19].

Among various learning resources, laboratory activities are considered one of the most effective ways to engage students actively in science learning and support the development of 21st-century skills. Learning resources are anything used to support the learning process of learners [20], [21]. Learning resources do not come solely from textbooks; they can also draw on the surrounding environment, natural phenomena, and students' real-life experiences [22]. Through laboratory work, students can make observations, conduct experiments, engage in discussions, and communicate their learning outcomes [23], [24]. However, laboratory activities in schools still face several challenges, such as monotonous activities, limited materials and equipment, insufficient utilization of local resources, and suboptimal integration of learning technologies. These conditions make laboratory activities less effective in fostering students' interest in learning and less supportive of critical thinking skill development. Therefore, innovation in laboratory learning design is needed to create more contextual, engaging, and meaningful learning experiences for students.

Innovative laboratory experiments are a learning strategy designed to enhance students' critical thinking skills and address the limitations of conventional laboratory experiments [25]. These experiments can be designed to utilize local resources, such as coconut water as a growth medium and *Aloe vera* plants as experimental subjects, ensuring that materials are easily accessible and that learning is closely aligned with students' daily lives. The advantage of this laboratory experiment is that students learn directly and actively, and can understand concepts through real-world experiences [26]. To support the implementation of the laboratory experiment, experimental steps can be presented in the form of digital posters that help students understand procedures, record results, analyze data, and conclude. This approach encourages active engagement and trains students' abilities in interpretation, analysis, evaluation, inference, and explanation, key indicators of critical thinking.

Previous research has shown that laboratory activities play a crucial role in enhancing students' critical thinking skills. Through laboratory activities, students are trained to observe, collect, and analyze data; solve problems; and draw conclusions based on experimental results [27]-[29]. Several studies also report that students' active involvement in laboratory activities helps them better understand concepts than when learning focuses solely on theoretical explanations [30]-[32]. Well-designed laboratory activities can train students to ask questions, evaluate experimental results, and make decisions based on evidence [33]. Although previous studies have demonstrated that laboratory activities can improve students' critical thinking skills, most studies still focus on conventional worksheets and printed laboratory materials. Research on digital poster-based laboratory media integrated with local resources in biology learning remains limited. In addition, previous studies rarely explicitly integrate critical thinking indicators into digital laboratory learning materials. Therefore, there is a need to develop innovative laboratory learning media that are contextual, technology-based, and capable of facilitating students' critical thinking skills.

Based on previous studies, the novelty of this research lies in the development of a digital poster-based learning medium that utilizes local resources, such as coconut water and *Aloe vera* plants. Based on the background described above, the research questions are: (1) How can one Design valid digital poster-based lab instructions regarding the effect of coconut water on the growth of *Aloe vera* plants? Moreover, (2) How can one evaluate the validity of the designed digital poster-based lab instructions regarding the effect of coconut water on the growth of *Aloe vera* plants?. This study is important because it provides an alternative biology laboratory learning medium that is contextual, accessible, and capable of supporting students' critical thinking skills through the integration of local resources and digital technology. The findings of this study are expected to

contribute to the development of innovative biology learning media, particularly digital laboratory materials that integrate local resources and critical thinking skills in science education.

2. RESEARCH METHOD

This study employs the Research and Development (R&D) research method. The R&D method is a research approach aimed at developing and producing an educational product and testing its feasibility through a systematic process. R&D emphasizes the stages of designing, developing, and evaluating learning products to ensure they align with learners' needs and characteristics [34]. The development model used in this study employs the 4D method. This method serves as the foundation for designing the learning media to be created. The design stages in the 4D method are Define (Definition), Design (Design), Develop (Development), and Disseminate (Dissemination) [35]. However, this study is limited to the development (Develop) stage and will be validated by subject-matter experts and instructional media experts, specifically, one biology lecturer and two biology teachers. Validation is conducted to assess the suitability and validity of the developed digital poster before its implementation in instruction.

The instrument used in this study is a validation sheet that assesses content/material, organization/presentation of material, language, and graphics. The validation instrument used in this study is based on the learning media validation instrument developed by Khafidhotur and Murtini [36], which covers the aspects of content, structure, language, and graphics. The instrument was then modified to align with the characteristics and objectives of the Digital Poster-Based Laboratory Guide media that were developed. Feasibility data were obtained from expert evaluations using a 1–5 Likert scale when assessing the media according to the questions provided below; the criteria are as follows: 5 = Excellent, 4 = Good, 3 = Fair, 2 = Poor, 1 = Very Poor [37]. The data collection method used involved distributing validation sheets to the validators. The collected data were analyzed descriptively by calculating the validation scores given by the expert validators. The analysis was conducted to determine the validity level of the developed product based on aspects of material, systematics, language, and graphics.

Subsequently, the results for each validation criterion score were calculated based on the validity formula for each criterion:

$$\text{Percentage validity} = \frac{\text{Total score obtained}}{\text{Maximum possible score}} \times 100\% \dots (1)$$

The research results were then categorized by reliability or validity by [38], as presented in Table 1.

Table 1. Validity assessment criteria for digital posters

Percentage	Criteria
76%-100%	Highly valid
56%-75%	Moderately valid
40%-55%	Low validity
0%-39%	Invalid

3. RESULTS AND DISCUSSION

In this study, the evaluation of digital poster quality focused on the development phase. This study utilized the 4D model; however, its implementation only covered three phases-Define, Design, and Develop-because the product had not yet been field-tested for practicality and effectiveness. This study remains focused on the development stage (Develop), specifically on the validity testing conducted by validators; therefore, the Disseminate stage is planned for a follow-up study. The Define stage involves identifying problems and student needs in conducting biology laboratory sessions through observation and interviews with teachers and students. The Design phase involves selecting the media format, preparing materials, structuring the poster, and designing the initial poster layout. Subsequently, the Develop phase involves the validation process conducted by validators to test the product's validity.

Definition Phase

In the definition phase, this study focused on identifying students' problems and needs regarding the implementation of biology laboratory sessions through observations and interviews with teachers and students at MA Al-Ma'arif Cempleng. The observations showed that the school did not yet have laboratory facilities, so laboratory activities had never been conducted. This situation led to a focus on theoretical delivery of material

and insufficient hands-on learning experiences. This indicates that limited facilities directly impact students' limited opportunities to build concrete conceptual understanding. This aligns with [39], which emphasizes that laboratory activities play a crucial role in enhancing students' conceptual understanding and scientific skills.

Interviews with teachers revealed that limited facilities and equipment are the main obstacles to conducting laboratory experiments. As an alternative, teachers occasionally show laboratory practice videos. However, the use of such media has not provided an optimal learning experience because students are not actively engaged. This indicates that passive learning is less effective in developing students' scientific process skills. This is supported by [40] and [41], who state that video-based learning without active interaction tends to be less effective in enhancing students' deep understanding. Meanwhile, interview results indicate that students struggle to understand the material due to the lack of hands-on laboratory activities. This reinforces the notion that theoretical learning without direct experience tends to result in shallow understanding. This aligns with [42], which states that active learning significantly enhances conceptual understanding compared to passive methods.

The interview results indicate that there is a growing need for alternative learning materials. Therefore, electronic posters containing lab procedure guidelines were developed to help students understand the steps of the lab experiment systematically. This is supported by [43] and [44], who state that digital-based learning media can help improve conceptual understanding, increase students' motivation to learn, and enhance their memory. Additionally, [45] and [46] demonstrate that posters as learning media have the advantage of presenting information concisely, engagingly, and in an easy-to-understand manner, thereby increasing students' attention and engagement in learning. Thus, posters integrated with technology are expected to help students understand the lab steps more clearly, increase engagement in learning, and facilitate access to materials.

Design Phase

The content of this digital poster is based on analysis results and theoretical foundations drawn from relevant, up-to-date references. The presentation of the material is systematically designed to ensure it is easily understood by students and aligned with the learning objectives. The Design features green, yellow, and blue as its primary colors. The choice of green and blue is associated with the environment, comfort, and calmness, thereby capturing visual attention; yellow enhances concentration, thereby supporting students' focus while using the poster [47].

The initial Design of this learning medium consists of a home screen (poster) displaying the lab title and an overview of the material. On this screen, there are selectable sections (clickable) that direct students to each main component within the learning media. This interactive Design allows students to access the material independently. It increases engagement in learning, as it has been stated that interactive media can enhance students' active engagement in the learning process [48], [49]. Several features of this interactive poster are systematically organized according to the flow of the laboratory activity, including learning outcomes and objectives, laboratory rules, theoretical background, research variables, equipment and materials, and laboratory procedures. The sequence of laboratory activities in this digital poster follows the stages of the scientific method: observation, data collection, analysis, and concluding [50].

Additionally, this sequence aligns with the critical thinking indicators proposed, which encompass interpretation, analysis, evaluation, inference, explanation, and self-regulation. However, in this study, the indicators are limited to five aspects: interpretation, analysis, evaluation, inference, and explanation. The decision to limit the indicators of critical thinking skills to five aspects excluding self-regulation was made because self-regulation falls within the metacognitive domain, which pertains to students' ability to monitor and control their own thinking processes. This aspect is often difficult to observe and measure directly in laboratory settings. Furthermore, self-regulation does not always appear clearly in critical thinking assessments and is more frequently discussed in the context of learning process management [51]. Based on the design process, a digital poster was developed as the learning medium. The appearance of this medium is shown in Figure 1.



Figure 1. Digital poster design based on a laboratory experiment

In Figure 1, the lab-based digital poster is designed systematically to present important laboratory information concisely in a single display. The poster includes objectives, tools and materials, activity steps, observation tables, and data analysis presented in an organized manner. Each section is interactive, allowing students to click on specific parts to access more detailed explanations. This feature helps students understand the laboratory procedures gradually, from general concepts to more detailed information [52]. The poster begins with a title and introduction to attract students' attention and connect the material to the learning context [53].

It also provides learning outcomes, objectives, and indicators to guide the practicum activities. The theoretical section explains plant growth concepts and the role of coconut water as a natural growth regulator. In contrast, the laboratory section presents variables, tools, materials, and procedures sequentially to support systematic experimentation [54]. In addition, the observation and data analysis section guides students in comparing treatment results, identifying differences, and interpreting factors affecting plant growth. The poster also includes conclusion guidelines, report formats, a glossary, and references to support scientific reporting. Navigation buttons such as home, next, and previous make the poster easier to use, while the visual design and color combinations help improve students' focus and engagement during learning [55].

Overall, the digital poster integrates knowledge and practical skills effectively, helping students better understand plant growth concepts and supporting the development of critical thinking through laboratory activities. This is in line with the findings of [56], which state that laboratory activities can improve science process skills and critical thinking through observation, data collection, analysis, and conclusion drawing.

Development Stage

Validation data for the lab-based digital poster were obtained from evaluations conducted by three validators on April 5 and 7, 2026, at MA Al-Maarif College and PGRI Ronggolawe University. The validators in this study were two biology teachers and one biology lecturer. The validity assessment was based on several aspects, namely content, organization, language, and graphics. In addition to providing assessments, the validators offered critiques and suggestions to improve the lab-based digital posters. The results of these critiques and suggestions are shown in Table 2.

Table 2. Criticisms and suggestions provided by the validators

Revised section	Before revision	After revision
Course Content	The poster does not explicitly explain the hormonal mechanisms of coconut water (cytokinins, auxins, gibberellins)	The article explains the hormonal content of coconut water and its physiological mechanisms regarding cell elongation and leaf formation in plants.
	It lacks interactive elements such as reference links.	There is a QR code that links to relevant scientific references.
	There are no research variables.	Research variables are included.
Graphics	The concentration of the administered coconut water is not specified (0%).	Coconut water application concentration: 0%
	The image quality is not optimal.	Image quality is already optimal.

Based on feedback and suggestions received, revisions were made to the lab-based digital poster to improve the product's quality. After the revisions were implemented, the product was validated by expert validators. The results of this validation are presented in Table 3.

Table 3. Validity Scores

Assessment Aspect	Validator Score			Average	Remarks
	Validator I	Validator II	Validator III		
Content	95%	90%	95%	93.3%	Highly valid
Systematics	92.5%	87.5%	92.5%	90.8%	Highly valid
Language	95%	90%	90%	92.3%	Highly valid
Graphics	83.3%	100%	100%	94.4%	Highly valid
Average criterion score (%)				92.7%	Highly valid

The validation results showed that the lab-based digital poster achieved an average validity score of 92.7%, categorized as highly valid. This finding indicates that the developed media is feasible for use in biology laboratory learning in terms of content, organization, language, and graphic Design. The results are in line with previous studies showing that ICT-based and Figma-based learning media obtained high validity scores of 86.8% and 92.13%, respectively [57], [58]. However, this study extends previous research by integrating laboratory activities, interactive digital features, and local potential into a single contextual learning medium.

The validation results from three validators on the content aspect yielded an average score of 93.3%, which is classified as highly valid. These results indicate that the content in the lab-based digital posters has been developed in accordance with the learning outcomes, indicators, and learning objectives to be achieved. The presented material contains concepts relevant to laboratory activities. Additionally, the material reflects key components of the scientific method, thereby supporting the optimal implementation of laboratory activities. The coherent, systematic, and contextual presentation of the material facilitates students' understanding of concepts. It helps them connect theory with practice, where structured material organization has been proven to aid integrated learning [59], [60]. In addition, the inclusion of scientific investigation components in the poster reflects constructivist learning principles, where students actively build understanding through direct learning experiences [61].

The systematic aspect received a score of 90.8%, placing it in the highly valid category. These results indicate that the poster content was organized sequentially, starting from theory, laboratory procedures, observation activities, and data analysis. A well-structured presentation helps students follow the learning stages more effectively and supports the achievement of learning objectives [62], [63]. The systematic arrangement of the material also allows students to understand laboratory activities step by step, thereby helping them connect concepts more easily and perform the practicum procedures in an organized manner.

The linguistic aspect received a score of 92.3%, placing it in the highly valid category. These results indicate that the language used was communicative, appropriate to students' developmental levels, and consistent with Indonesian spelling rules. Clear and understandable language can increase students' comprehension and learning interest [64], [65]. The use of simple, clear, and consistent language in the developed media also supports students in independently understanding laboratory instructions and scientific concepts without causing ambiguity during the learning process.

The graphic design aspect obtained the highest score of 94.4%, indicating that the visual elements, such as layout, typography, color combinations, and images, effectively supported information delivery. Attractive and balanced visual Design can improve students' attention and engagement during learning [66], [67]. The appropriate combination of visual elements in the developed poster also helped present information more clearly and made the learning material easier for students to understand. In addition, the consistent use of typography and layout enhanced the readability and organization of the learning content [68].

The validated product was then packaged in the form of a digital poster accessible through a Heyzine web link. Students can access the media flexibly through smartphones or laptops without downloading additional applications. This finding is consistent with previous studies showing that web-based digital media can increase learning flexibility, engagement, and independent learning opportunities [69]. The web-based and interactive characteristics of the developed poster, therefore, become important strengths in supporting flexible, accessible, and student-centered learning.

The findings of this study indicate that the developed digital poster-based laboratory media integrated with local potential can support meaningful biology learning and potentially facilitate students' critical thinking skills. The integration of interactive features, contextual materials, and laboratory activities enables students to connect theoretical concepts with real-life experiences, thereby supporting constructivist learning principles. This study contributes to the development of innovative biology learning media by combining digital technology, laboratory activities, and local resources into a contextual and interactive learning medium. Unlike

previous studies that mainly focused on general digital learning media, this study specifically emphasizes laboratory-based biology learning integrated with local potential to support meaningful learning experiences.

This study was limited to the validity testing stage and did not include practicality or effectiveness testing involving students in classroom learning. Therefore, the impact of the developed media on students' critical thinking skills and learning outcomes has not yet been empirically measured. Future studies are recommended to examine the practicality, effectiveness, and students' responses toward the developed media through classroom implementation involving larger samples and different educational settings.

4. CONCLUSION

This study successfully developed a digital poster-based laboratory learning medium on the effect of coconut water on the growth of *Aloe vera*, which was categorized as highly valid, with an overall validity score of 92.7%. The developed medium fulfilled the aspects of material, systematics, language, and graphics, indicating its feasibility as a biology learning medium. This study contributes to the development of interactive digital laboratory media integrated with local resources to support critical thinking-oriented learning. However, further research is needed to examine the practicality and effectiveness of the developed media through classroom implementation.

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AUTHOR CONTRIBUTIONS

S.L. was responsible for developing the research design, collecting and analyzing data, and writing the manuscript. I.C., as the supervising instructor, assisted in developing the research concept, validating the instruments and materials, providing guidance on research methods, and making revisions to improve the quality and clarity of the manuscript. All authors have read and approved the final version of this manuscript.

CONFLICTS OF INTEREST

The author(s) declare no conflict of interest.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY

The authors declare that no artificial intelligence (AI) tools were used in the generation, analysis, or writing of this manuscript. All aspects of the research, including data collection, interpretation, and manuscript preparation, were carried out entirely by the authors without the assistance of AI-based technologies.

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