Integrated Science Education Journal
Vol. 7, No. 3, May 2026, pp. 519~529
ISSN: 2716-3725, DOI: 10.37251/isej.v7i3.3256

Research Article

Designing Biology Lab manuals Based on Local Resources to Enhance Critical Thingking Skills

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Article Info

Article history:

Received Mar 11, 2026
Revised Apr 18, 2026
Accepted May 21, 2026
OnlineFirst May 31, 2026

Keywords:

Biology Education
Critical Thingking Skills
Electronics Lab Manual
Local Resources
Moringa Leaves

ABSTRACT

Purpose of the study: Biology learning in the 21st century requires innovative, contextual learning resources that support students' critical thinking skills. However, electronic biology practicum instructions that integrate local potential are still limited in biology education. Therefore, this study aimed to develop and validate local-potential-based electronic biology practicum instructions using *Moringa oleifera* L. leaf extract to assess its effects on *Allium cepa* L. growth and support students' critical thinking skills.

Methodology: This study employed the Research and Development (R&D) method using the 4D model; however, the research was limited to the development stage. The developed product was an electronic biology practicum instruction that integrated local potential by using *Moringa oleifera* leaf extract. Product validity data were collected using validation sheets assessed by three expert validators covering aspects of material, systematic presentation, language, and graphics.

Main Findings: The results showed that the average validity score was 90.8%, indicating it is very valid. The validity details included the material aspect (91.6%), systematic presentation aspect (90%), language aspect (88.5%), and graphic aspect (93.3%). These findings indicate that the developed electronic practicum instructions met the validity criteria and are suitable for use in biology learning.

Novelty/Originality of this study: The novelty of this study lies in integrating local potential and digital technology into electronic biology practicum instruction to create a more contextual and meaningful learning experience. In addition, the developed product has implications for supporting students' critical thinking skills and for promoting contextual biology learning relevant to students' daily lives.

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1. INTRODUCTION

Biology education in the 21st century requires the development of higher-order thinking skills, including critical thinking, creativity, collaboration, and communication, as core competencies for students [1]-[4]. Critical thinking skills are essential, as they involve the ability to analyze natural phenomena, evaluate evidence, and make decisions based on scientific reasoning and empirical data, particularly in the context of biology lab work [5]-[7]. However, students' critical thinking skills remain relatively low because biology instruction tends to be theoretical and lacks connections to real-world contexts relevant to students' experiences [8], [9]. One approach considered effective in addressing this issue is contextual learning.

Contextual learning is an educational approach that connects scientific concepts to events or phenomena in everyday life, thereby helping students understand the material in a more meaningful and practical way within real-world contexts [10]-[12]. This approach has been shown to enhance students' critical and creative thinking skills because the learning becomes more relevant to their experiences [13]-[15]. Contextual learning also plays a role in fostering local wisdom and an awareness of the potential of the surrounding environment [16]-[18]. Contextual learning in biology is most effective when supported by the utilization of local resources. Local resources include all natural resources, cultural elements, and local knowledge found in the students' immediate surroundings that can be used as learning resources [19]-[21]. The use of local resources in biology education not only strengthens deep understanding of concepts and also develops students' environmental awareness and enhances the relevance of learning to their daily lives [22]. However, in order for contextual learning based on local potential to be implemented systematically and purposefully in the classroom, learning materials are needed that can guide students clearly and systematically.

As education evolves, the conduct of biology lab sessions needs to be supported by digital learning resources so that these sessions can be conducted in a systematic and efficient manner and be easily understood by students [23]. One relevant digital learning resource is the electronic lab manual. An electronic lab manual is a digital lab guide that contains structured and interactive instructions for lab activities; it is used to facilitate the conduct of lab sessions and enhance the effectiveness of lab-based learning in classrooms and laboratories [24]. The use of electronic lab manuals has been shown to enhance students' independent learning, the effectiveness of lab sessions, and their conceptual understanding [25]. Electronics lab manuals allow for the presentation of course material, procedures, illustrations, and observation sheets in a more systematic and easily accessible manner for students [26].

Several previous studies have developed digital-based laboratory manuals or guidelines in the context of biology education. According to [27] developing e-pocket book-based lab manuals for growth and development topics can enhance students' psychomotor skills. According to [28] developing digital biology lab manuals on animal tissue that are suitable for use in laboratory activities. According to [29] shows that digital lab guides developed using the Project-Based Learning model can foster 21st-century skills. According to [26] the development of guided inquiry-based electronic lab manuals for biology instruction, validated by experts and deemed suitable for use.

Although previous studies have shown that electronic laboratory manuals can support biology learning and improve students' laboratory performance, most studies still focus on general biology materials and have not integrated local resources into laboratory activities. In addition, previous studies rarely emphasize the integration of contextual learning and critical thinking indicators in electronic apakah itu suflaboratory manuals. As a result, laboratory learning tends to be less relevant to students' daily lives and has not optimally facilitated the development of critical thinking skills. Therefore, there is a need to develop a local-potential-based electronic biology lab manual that integrates contextual learning to support students' critical thinking skills.

Based on previous research on the electronic lab manuals discussed above, the research questions in this study are: (1) How can we design biology electronic lab manuals based on local resources to enhance critical thinking skills? and (2) How can we assess the validity of biology electronic lab manuals based on local resources for enhancing critical thinking skills? The objectives of this study are to (1) design local-potential-based electronic biology lab guidelines to improve critical thinking skills, and (2) describe the validity of local-potential-based electronic biology lab guidelines for improving critical thinking skills.

2. RESEARCH METHOD

This study is an R&D (Research and Development) study. Research and Development (R&D) is a research method aimed at developing a specific product while testing the extent to which that product is effective in use [30]. The development model used in this study is the 4D model, which consists of four stages: Define, Design, Develop, and Disseminate [31]. However, this study is limited to the development phase, specifically the product validation phase conducted by expert validators (covering content, structure/presentation of content, language, and graphics). The dissemination phase has not yet been implemented because it requires further research to test the practicality and effectiveness of the electronic biology lab manuals in the learning process.

Product validation involved three expert validators, consisting of biology education lecturers and biology teachers. The validators were selected based on their expertise and experience in the field of biology education and the development of educational media. The educational product developed in this study is an electronic biology lab manual on the use of Moringa oleifera L. extract to promote the growth of Allium cepa L. shoots.

The instrument used in this study was a validation sheet that assessed the content, organization or presentation of the material, language, and graphics. The validation instrument used was based on the learning media validation instrument developed by Rahmawati and Cintamulya [32], which covers content, structure, language, and graphics. This instrument was then modified to suit the characteristics and objectives of the electronic biology lab manual being developed. The data analysis techniques used in this study were qualitative descriptive analysis and quantitative descriptive analysis. Qualitative descriptive analysis was used to analyze the comments, critiques, and suggestions from the validators as a basis for revising and refining the product during the development stage. Meanwhile, quantitative descriptive analysis was used to analyze the product validity scores obtained from the validation sheets. The rating scale used in this study was the Likert scale presented in Table 1 [33].

Table 1. Scores and criteria provided on the validation sheet

Score	Criteria
5	Excellent
4	Good
3	Fair
2	Poor
1	Bad

The validity scores obtained were then analyzed using the following formula:

$$P = \frac{f}{n} x\ 100\% \ldots (1)$$

Notes:
P = Feasibility percentage
f = Expert evaluation score
n = Maximum evaluation score

The research results were then categorized according to their feasibility or validity and are presented in Table 2 [34].

Table 2. Validity Categories

Percentage	Category
0% - 20%	Invalid
21% - 40%	Somewhat Invalid
41% - 60%	Moderately Valid
61% - 80%	Valid
81% - 100%	Higly Valid

3. RESULTS AND DISCUSSION

In this study, the quality testing of electronic lab manuals focused on the development phase. The 4D model was used, but its implementation was limited to only three phases definition, design, and development because the product had not yet been field-tested for practicality and effectiveness. This study emphasizes the development stage, specifically focusing on the validity testing conducted by validators; therefore, the dissemination stage is planned for a subsequent study.

The definition phase involves identifying problems and analyzing students' needs in conducting biology lab sessions through classroom observations and interviews conducted with teachers and student. The design phase includes determining the format of the media, preparing materials, structuring the electronic lab instructions, and creating a preliminary design. The development phase involves a validation process conducted by validators to validate the developed product as a learning medium.

3.1 Definition Phase

In the definition phase, this study focused on identifying issues and analyzing students' needs regarding the implementation of biology laboratory sessions. This was conducted through observations and interviews with teachers and students at MA Ma'arif Cumpleng. Based on the observation results, it was found that the school does not yet have laboratory facilities, so laboratory activities have never been conducted, and learning tends to focus on the theoretical delivery of material. In fact, biology learning accompanied by laboratory activities has been proven to have a significant relationship with the improvement of students' critical thinking skills [7].

Interviews with teachers revealed that inadequate facilities and infrastructure were the primary factors preventing the implementation of laboratory experiments. As an alternative, teachers occasionally use laboratory experiment videos in their lessons; however, this has not been sufficient to provide students with an optimal learning experience. This aligns with research indicating that direct engagement through laboratory experiments provides a more meaningful learning experience than passive learning [35]. On the other hand, students reported that they had difficulty understanding biology material due to the lack of hands-on laboratory experience. This situation can lead to low levels of critical thinking skills among students in biology classes [36].

Based on the interview results, it can be concluded that there is a need for a learning resource capable of facilitating laboratory activities in an alternative manner. Therefore, an electronic laboratory guide was developed to support laboratory activities. The development of this laboratory guide has also been shown to help improve students' critical thinking skills in biology education [37]-[39]. In addition, digital visual media can enhance students' conceptual understanding [40]-[42]. Thus, lab manuals integrated with technology are expected to help students understand the steps of the lab in a more systematic and clear manner, increase engagement in the learning process, and facilitate flexible access to learning materials.

3.2 Design Phase

The laboratory instruction materials developed in this study were designed based on the results of the analysis and combined with theoretical foundations from various relevant sources regarding biology education and critical thinking skills. The design of these materials uses green and blue as the primary colors. The selection of green and blue is based on their association with the environment, comfort, and tranquility. The combination of these two colors creates a cool and harmonious visual impression, thereby enhancing the media's visual appeal and helping to capture students' attention during the learning process [43].

The initial design of this learning material begins with the cover page of the electronic lab manual, which includes the lab title and an overview of the material to be studied. This lab manual is equipped with integrated technology in the form of a scannable barcode that provides access to instructional videos. This feature was developed to support more interactive learning and to give students opportunities to learn independently [44]. The use of video- and visual-based learning materials is known to increase student engagement and understanding in the learning process [45], [46].

The components of this laboratory manual are systematically organized according to the sequence of laboratory activities, including learning outcomes, learning objectives, laboratory rules, theoretical foundations, infographics on internal and external factors, equipment and materials, and laboratory procedures. These components are designed to follow the stages of the scientific method observation, data collection, analysis, and drawing conclusions to help students understand the scientific process in a logical sequence [47].

In addition, the sequence of laboratory activities in these electronic laboratory instructions is based on the indicators of critical thinking skills identified by Peter A. Facione, which include interpretation, analysis, evaluation, inference, explanation, and self-regulation [48]. However, in the context of this study, the indicators used are limited to five aspects: interpretation, analysis, evaluation, inference, and explanation; the restriction of critical thinking skill indicators to five excluding self-regulation was implemented because self-regulation is metacognitive in nature, meaning it relates to the ability to monitor and control students' internal thought processes, making it difficult to observe and measure directly during laboratory activities. Furthermore, this aspect is not always explicitly integrated into critical thinking assessments and is more frequently examined within the context of learning management [49]. Based on the results of the design process, a learning resource in the form of digital laboratory instructions was developed; these instructions are systematically organized and integrated with learning technology. This resource serves not only as a laboratory guide but also as a tool for developing students' critical thinking skills. The resource is illustrated in Figures 1–11.

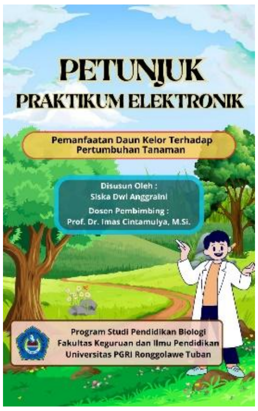

Figure 1. Cover image

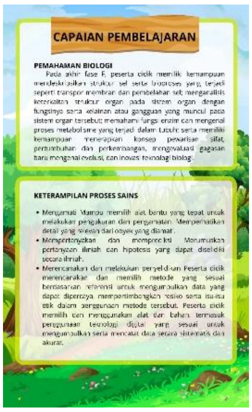

Figure 2. Overview of Learning Outcomes

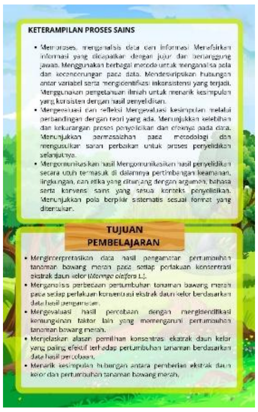

Figure 3. Learning Objectives

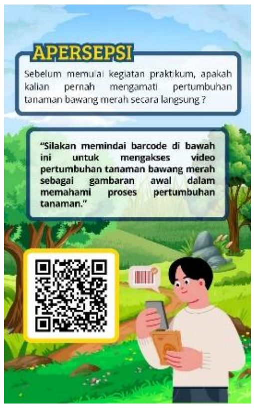

Figure 4. Apersepsi Interface

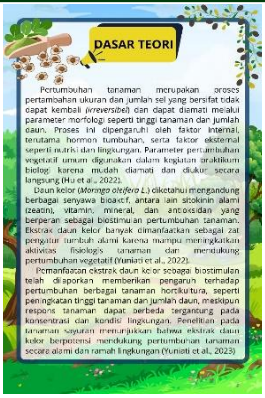

Figure 5. Basic Overview of the Theory

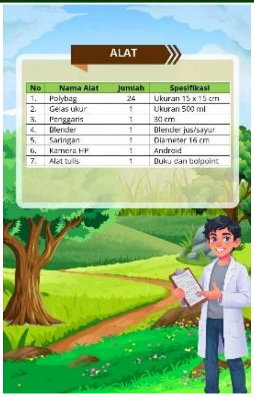

Figure 6. Tool Interface

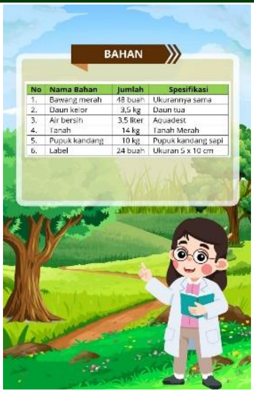

Figure 7. Materials Display

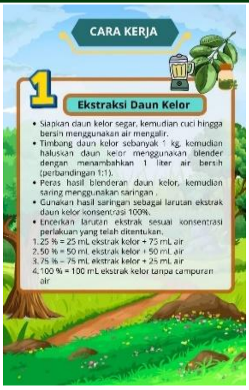

Figure 8. How It Works

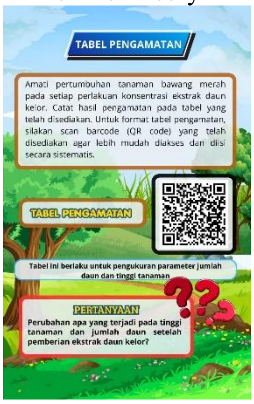

Figure 9. Observation Table Display

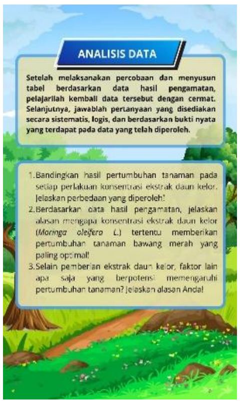

Figure 10. Data Analysis Display

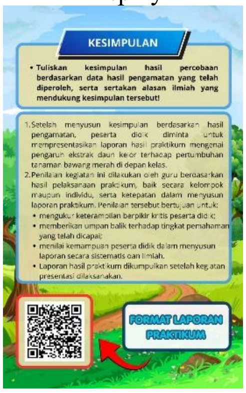

Figure 11. Conclusion Screen

The laboratory manual developed in this study was systematically designed to explore the use of moringa leaf extract (*Moringa oleifera L.*) to promote Allium Cepa L growth as a learning context. At the beginning, the manual features a cover page containing the title of the laboratory session and a brief description as an introduction, aimed at providing students with an initial overview of the activities to be conducted. This material is equipped with learning outcomes and learning objectives that are clearly and specifically formulated to serve as guidelines for conducting the laboratory session. The purpose of including these components is to ensure that students have a comprehensive understanding of the expected competencies and the direction of the activities to be carried out [50].

The theoretical section presents concepts related to plant growth and the role of moringa leaf extract as a natural growth regulator containing various hormones and nutrients. This material serves as a conceptual foundation for students before they conduct laboratory experiments, ensuring that the learning process is not merely procedural but is also supported by a solid theoretical understanding [51]. The laboratory components are organized comprehensively and systematically, covering equipment and materials as well as step-by-step procedures presented in a logical sequence. The activity stages begin with preparation, the preparation of moringa leaf extract solutions at varying concentrations, the planting process, and conclude with observation activities. This structured presentation of procedures is intended to help students conduct the laboratory experiment accurately and effectively [52]. Next, the observation Table and data analysis section is provided as a tool for students to record, process, and interpret experimental data. Through this activity, students are trained to compare results across different treatments, identify differences, and analyze the factors that influence plant growth. In the final section, the resource includes a conclusion, a glossary, and a bibliography. The conclusion helps students formulate final results based on the data obtained [53].

Overall, this laboratory manual serves not only as a guide for conducting activities but also as a learning tool capable of integrating knowledge with skills. Through the laboratory activities conducted, students are expected to understand the concept of plant growth while developing critical thinking skills through the processes of observation, experimentation, and data analysis. This is supported by research showing that laboratory-based learning has a positive correlation with students' critical thinking abilities because it provides hands-on experience and encourages students to conduct independent analysis [54]. In addition, the use of interactive, activity-based learning materials has also been shown to enhance critical thinking skills by actively engaging students in problem-solving and decision-making processes [55].

3.3 Development Phase

The validation data for the electronic lab manual were obtained from the evaluations of three validators, conducted on April 5 and 7, 2026, at MA Al–Ma'arif Cumpleng and PGRI Ronggolawe University. The validators in this study consisted of two biology teachers and one biology lecturer. The validity assessment was based on several aspects, namely content, presentation or organization, language, and graphics. In addition to providing assessments, the validators also offered critiques and suggestions for improving the developed electronic lab manual. The results of the validators' critiques and suggestions are presented in Table 3.

Table 3. Comments and suggestions from validators regarding the Electronic Lab Manual

Revised Sections Content	Before the Revision	After the Revision
Materials	• The theoretical section does not briefly explain the mechanism of action of zeatin/cytokinin from Moringa oleifera L extract on cell division in Allium cepa L plants	• Has briefly explained the mechanism of action of zeatin/cytokinin from Moringa oleifera L extract on cell division in Allium cepa L plants
	• There are currently no short videos (1–2 minutes) showing the growth of Allium cepa L in time-lapse	• There is already a short video (1–2 minutes) showing the growth of Allium cepa L in time-lapse
	• There is no brief infographic box on intrinsic and extrinsic factors	• There is already a brief infographic box on intrinsic and extrinsic factors
Graphics	• The image resolution in the table of tools and materials is still below 150 dpi	• The image resolution in the table of tools and materials is over 150 dpi

Based on the feedback and suggestions received, revisions were made to the electronic lab manual as part of an effort to improve the quality of the product, particularly in terms of content and graphic design. After these revisions were implemented, the product was validated by expert validators to determine its level of validity. The results of this validation are presented in Table 4. The validity of the laboratory manual was assessed by three expert validators, who evaluated the content, structure, language, and graphics. The average scores from the validation process are presented in Table 3.

Table 4. Average Validation Results

No	Assessment criteria	On average	Category
1	Materials	91.6 %	Highly Valid
2	Outline	90.0 %	Highly Valid
3	Linguistic	88.5 %	Highly Valid
4	Graphics	93.3 %	Highly Valid
	Average Score Criteria	90.8 %	Highly Valid

Overall, the validation results for the electronic lab manual achieved an average of 90.8%, falling into the highly valid category. This indicates that the developed learning material meets the validity criteria, particularly in terms of content and graphics areas that were the focus of improvement. The results of this study indicate that digital learning materials have a high level of validity, consistent with previous research Lestari & Cintamulya [56] which reported that information and communication technology (ICT)-based learning materials achieved a validity score of 86.8%, falling into the highly valid category. In addition, Rohmah et.al [57] It also shows that the digital design application-based learning medium (Figma) achieved a validity score of 92.13%. When compared to this result, the validity score in this study 90.8% falls into the highly valid category, indicating that the developed medium is of high quality and is academically acceptable among validated digital biology learning media.

The content aspect received a score of 91.6%, the systematic aspect 90%, the language aspect 88.5%, and the graphic design aspect 93.3%, all of which fall into the highly valid category. These results indicate that the lab manual has been systematically organized, uses clear language, and features an attractive layout that is easy for students to understand. The content aspect received a score of 91.6% and was categorized as highly valid indicating that the content in the electronics lab manual has been developed in accordance with the learning outcomes, indicators, and learning objectives to be achieved. The presentation of relevant, scientifically grounded content has been shown to enhance students' conceptual understanding [58]. In addition, the integration of theory and practice in learning can enhance students' critical thinking skills [59]. Practical based materials have also been shown to deepen conceptual understanding since students are directly engaged in the scientific process [60].

The systematic aspect received a score of 90% and was categorized as highly valid. The lab instructions were organized in a systematic and structured manner, covering learning outcomes, objectives, equipment and materials, procedures, and analysis and conclusions. This systematic organization of the material has proven effective in helping students understand concepts in a step-by-step and logical manner [36]. A well-organized structure also makes it easier for students to conduct laboratory experiments independently, as the steps are presented clearly and in a logical sequence. This is consistent with the research Ibrahim et al [61] which states that structured instructional materials can enhance students' independent learning. In addition, a clear sequence of laboratory activities can minimize errors in the conduct of experiments [62].

The linguistic aspect received a score of 88.5%, falling into the highly valid category. This indicates that the language used conforms to the rules of proper and correct Indonesian, is communicative, and is easily understood by students. The sentences used in this material are not only informative but also provide clear guidance for conducting the lab activity, particularly regarding the experimental steps and data analysis, thereby minimizing errors in understanding the instructions. Additionally, the language used in these lab instructions has been adapted to the students' cognitive development level, ensuring that the messages are well-received without causing confusion or ambiguity [63]. It is well known that communicative and easy-to-understand language can increase students' interest in learning and their engagement in the learning process [64].

The graphic design aspect received an average score of 93.3%, falling into the highly valid category. The layout of the lab instructions was designed with good visual design principles in mind, including a balanced layout, clear image quality, appropriate font size selection, and a harmonious and appealing color scheme. This well-organized visual presentation assists students in understanding the materia more easily because the information is presented clearly and in a structured manner [65]. In addition, the selection of colors, illustrations, and the arrangement of visual elements are balanced so as not to appear excessive, yet still capture the students' attention. This creates a comfortable reading experience while helping students focus on the material being presented. The appeal of a learning medium is known to be greatly influenced by the quality of its visual design [66]. In addition, the use of visual elements such as images and QR codes in this medium also makes learning more interactive. Interactive digital media has been shown to increase student engagement and make the learning process more effective [67].

This high level of validity indicates that e-learning materials are well-suited to the demands of 21st-century learning, which integrates digital technology, scientific activities, and active student engagement [68]. In addition, the use of electronic media in education has been shown to enhance the effectiveness and flexibility of student learning [69]. Digital media can also significantly increase student engagement in the learning process [70]. The validated products are then packaged as electronic lab manuals, which have been uploaded to the Heyzine website and can be accessed via the provided link. A web-based format was chosen for these electronic lab manuals because it is user-friendly and flexible. This format does not require storage space on devices, making it more efficient and practical for students to use [71]. The digital book-like interface makes it easier for students to read and follow lab instructions. This aligns with research showing that the use of Heyzine-integrated media can promote students' active participation and improve access to learning materials [72].

The uniqueness of this study lies in the integration of local resources through the use of Moringa oleifera L. extract in electronic biology lab manuals, combined with digital technology and indicators of critical thinking skills. Unlike previous studies, which generally focused only on general digital lab materials, this study integrates contextual biology learning based on local resources, thereby creating a more meaningful and interactive lab experience. Therefore, the developed product serves not only as a lab guide but also as a learning medium that supports the development of students' critical thinking skills. The results of this study indicate that biology lab manuals based on local resources can serve as an alternative learning resource for schools with limited laboratory facilities. The integration of digital technology into lab activities also allows students to access learning materials more flexibly and independently [73]. As a result, the developed product is aligned with 21st-century learning requirements and supports more meaningful, student-centered biology learning. In general, the research findings indicate that electronic lab resources that integrate local resources and digital technology have strong potential to support contextual and meaningful biology learning in the 21st century. Integrating local resources into digital lab activities can provide students with more relevant learning experiences while supporting the development of critical thinking skills through active engagement in scientific activities [74].

4. CONCLUSION

Based on the research findings, it can be concluded that the developed electronic biology lab manual based on local potential using *Moringa oleifera* L. extract on *Allium cepa* L. growth is categorized as highly valid, with an average validity score of 90.8%. The material, systematic presentation, language, and graphic aspects all achieved highly valid criteria. These findings indicate that the developed electronic lab manual is appropriate to support contextual and technology-based biology learning while facilitating students' critical thinking skills through scientific activities. The integration of local potential into digital laboratory learning also provides more meaningful and relevant learning experiences for students. However, further studies are still needed to examine the practicality and effectiveness of the developed product in classroom learning.

ACKNOWLEDGEMENTS

The author would like to thank the academic advisor for providing guidance, mentorship, and motivation throughout the research process and the writing of this article. Thanks are also extended to the school administration for granting permission and assisting with the research, as well as to the expert validators who provided suggestions and feedback, thereby improving the developed product. It is hoped that this research will contribute to the future development of biology education.

AUTHOR CONTRIBUTIONS

S.D. contributed to designing the study, gathering and analyzing the data, and preparing the manuscript. I.C., acting as the supervisor, contributed to formulating the research concept, validating the research instruments and materials, guiding the research methodology, and revising the manuscript to enhance its quality and clarity. The final manuscript was reviewed and approved by all authors.

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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