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Development of Biology Laboratory Equipment Work Instructions Using QR Codes as a Learning Resource for Biology Education Students

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ABSTRACT

This study aims to develop an E-atlas of laboratory equipment operation instructions, utilizing QR codes as a learning resource for biology education students. The objective is to enhance students' understanding of laboratory procedures through a mobile learning medium that integrates images, descriptions, and videos. The product was developed using the 4D model and tested for both validity and practicality. Data were collected through observations, interviews, and questionnaires involving experts, lecturers, and students. The analysis covered problem identification, student needs, curriculum alignment, and lecturer requirements. The product was designed using Canva Pro and Flip PDF Professional, ensuring compatibility with both computer and smartphone platforms. The validation results indicated very high validity, with 100% from material and media experts, and 92.5% from language experts. Practicality trials with biology education students yielded a score of 88.78%, while lecturer assessments showed a score of 96.42%. These findings demonstrate that the QR code-based electronic atlas is a valid, practical, and effective learning resource for biology laboratory activities.

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E-atlas, Laboratory, Learning Resource, QR Code, Work Instruction

Introduction

Education equips individuals with the knowledge, skills, and expertise necessary for both personal and societal development. As outlined in Government Regulation No. 57 of 2021 on National Education Standards, education enables learners to develop their potential, intelligence, morality, and competencies. In the digital age, educational practices have undergone significant changes, integrating technology to enhance both access to and the quality of learning (Nashrullah et al., 2024). This transformation has also affected biology education, which now incorporates digital tools to facilitate interactive and comprehensive learning.

Biology education employs various approaches, including laboratory-based practical activities that allow students to apply theoretical knowledge in real-world settings (Maulina et al., 2021). These practices help students solidify their understanding of the concepts they study (Sari et al., 2019). Effective learning encourages self-directed study beyond the classroom, a strategy that enhances knowledge, attitudes, and practical skills (Oishi, 2020). Self-directed learning depends heavily on easy access to relevant information, often provided through the internet. One such resource is the e-atlas, a digital guide to laboratory equipment that features interactive multimedia such as images and videos. This medium offers both accessibility and interactivity, making it easier for students to understand and properly use the equipment (Ahmad et al., 2023).

At the Biology Laboratory of UIN Sulthan Thaha Saifuddin Jambi, QR codes are attached to some laboratory instruments, linking to Google Drive documents that provide information about the tools. While QR codes offer a paperless method of delivering information, their current implementation is insufficient for effectively engaging students. Despite the availability of these QR codes, students' interest and usage remain limited during practical sessions.

A needs analysis conducted through questionnaires with biology education students revealed that 62% of students were unsure about how to use certain laboratory instruments, despite 73% claiming they could operate them. This discrepancy suggests a gap between practical tool use and adherence to Standard Operating Procedures (SOPs). Additionally, although many students attempted to use the QR codes, they found the content difficult to understand, and the documents unengaging. These issues highlight the need for a more practical, accessible, and engaging learning resource in the form of an e-atlas, which can provide visual guidance in a digital format. The e-atlas, as a mobile learning tool containing logically sequenced images, annotations, and videos, can improve material comprehension and increase student engagement (Setiawati, 2018).

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This study addresses the gap in existing QR-based laboratory guides by developing an e-atlas with integrated QR codes for laboratory equipment instructions. The novelty of this approach lies in its enhanced interactivity and visual appeal, responding to students' need for clear, concise, and accessible learning resources. By utilizing QR codes, students can easily access work instructions that align with SOPs, providing immediate and relevant information without the need to search for additional resources. This not only increases accessibility but also fosters student motivation and engagement—key components of effective learning (Nugraha et al., 2023).

In this context, the study focuses on the development, validation, and testing of the practicality of this e-atlas as a learning resource for biology education students. The development process aims to provide a practical, informative tool that enhances laboratory learning through digital interactivity, meeting students' needs and technological expectations.

Methods

This This study was conducted at the Mathematics and Natural Sciences Laboratory of UIN Sulthan Thaha Saifuddin Jambi from February 26 to March 10, 2025. The participants were biology education students who had completed the Biology Laboratory Knowledge course in the even semester. A purposive sampling technique was used to select participants who were familiar with the laboratory tools and procedures.

The study employed a Research and Development (R&D) method, utilizing the 4D development model (Define, Design, Develop, and Disseminate), with the research focusing solely on the development stage.**Procedure**

Define Stage

The initial stage involved collecting data through interviews with course instructors, observations of the biology laboratory, and questionnaires distributed to students. This data helped identify the learning challenges and needs of students, forming the basis for designing the e-atlas of laboratory equipment work instructions using QR Codes.

Design Stage

In this stage, the product was developed based on the identified needs, using Canva Pro for design and Flip PDF Professional for creating an interactive digital flipbook. These tools allowed for easy access to the learning resources across various devices. The use of interactive digital media is considered effective in supporting students' self-directed learning, enhancing learning motivation, and strengthening conceptual understanding both visually and practically (Luthfi, & Surya, 2024). In the context of higher education, Flip PDF Professional based media have also been proven to be valid and practical as modern learning resources that are responsive to students' needs (Purnamasari & Risqa, 2023).

Develop Stage

The product underwent validation by a team of experts, including subject matter experts, media experts, and language experts, to ensure its content, design, and readability met the necessary standards for learning resources.

Data Analysis

The collected data were analyzed in two ways: validity and practicality. Validity analysis was based on expert evaluations, while practicality analysis was derived from instructor and student feedback. The percentage scores were calculated by dividing the total score by the maximum possible score, then multiplying by 100%.

Table 1. Percentage Categories

Assessment	Category
81%-100%	Highly Valid
61%-80%	Valid
41%-60%	Moderately Valid
21%-40%	Invalid
0%-20%	Highly Invalid

Source: Isnaini, 2022

Results and Discussion

The e-atlas is accessible via QR codes. The 4D development model was used, but it was applied only up to the "Develop" stage due to limitations in time, cost, and resources. This model was chosen because it provides a systematic approach to designing and evaluating digital learning tools, which has proven effective in the development of electronic-based learning resources (Maulida et al., 2023).

Table 2 presents the expert evaluation results. Both the Subject Matter Expert and Media Expert rated the product at 100%, while the Language Expert gave it a rating of 92.5%. The overall average validity score from all experts was 97.5%, classifying the product as highly valid. This high score reflects the product's strength in content, media design, and language, confirming that the e-atlas meets the necessary standards for a learning resource. These findings align with Damayanti & Rusimamto (2020), who emphasized that high content validity ensures the material aligns with the expected competencies, making the media appropriate for use in the learning process. Additionally, a well-structured SOP for laboratory equipment serves as a guideline for users, acts as a communication tool between users and laboratory supervisors, and ensures that laboratory practices are conducted consistently and in compliance with established

standards (Pratiwi et al., 2024). From a linguistic perspective, the use of precise terminology and easily understandable explanations further supports students' comprehension of laboratory work instructions.

Table 2. Expert Evaluation Result

Field of Expertise	Score	Description
Subjek Matter Expert	100%	Highly Valid
Media Expert	100%	Highly Valid
Language Expert	92.5%	Highly Valid

Note: based on Likert scale interpretation

After the e-atlas was validated, it was tested for practicality by both course instructors and students. Table 3 shows the evaluation results by course instructors, with DN scoring 92.85% and MN giving a perfect score of 100%, resulting in an average practicality score of 96.42%. Instructors noted that the e-atlas has a clear information structure, an attractive layout, and facilitates explanations for students in both independent learning and laboratory practice.

Table 3. Evaluation Result by Lecturer in Charge of The Course

Name	Score	Description
DN	92.85%	Highly Valid
MN	100%	Highly Valid

Practicality evaluations by students were conducted in two phases: a small group trial involving 7 students and a large group trial with 25 students. Table 4 presents the results from these trials. The small group trial had a score of 86.90%, while the large group trial scored 90.66%. The average practicality score from all trials was 91.32%, indicating that the e-atlas is highly practical and effective for laboratory learning activities. This finding is consistent with Prasetyo & Fatmawati (2020), who stated that interactive and easy-to-use learning media improve the efficiency of the learning process.

Table 4. Average Evaluation Result by Students

Trial Group	Score	Description
Small Group	86.90%	Highly Valid
Large Group	90.66%	Highly Valid

In the results section, Figure 1 displays the interface of the e-atlas, showing how it provides easy access to laboratory tool information. This interface is designed to be user-friendly and accessible, allowing students to navigate easily through the content. Figure 2 shows the QR Code that can be scanned by users to directly access the laboratory equipment work instructions, making it a highly interactive and mobile learning resource.

Figure 1. Interface of The E-Atlas of Biology Laboratory Equipment Work Instructions

Figure 2. QR Code of E-Atlas

The findings from this study demonstrate that the e-atlas of biology laboratory equipment work instructions using QR codes is both highly valid and highly practical. The high validity scores, with an average of 97.5%, confirm that the product meets the necessary standards for content, media, and language. This high validity score aligns with the work of Damayanti & Rusimamto (2020), who emphasized the importance of content validity in ensuring that educational resources align with the competencies expected of students.

However, despite the 100% validity scores from the subject matter and media experts, a critical discussion is necessary. While the high scores are promising, they may indicate a potential bias, as the evaluators were likely familiar with the e-atlas, which could have led to a more favorable evaluation. Future studies should involve a more diverse group of experts and participants to mitigate this potential bias and improve the generalizability of the results.

The high practicality scores, with an average of 91.32%, indicate that the e-atlas is well-received by both instructors and students. This result supports the findings of Prasetyo and Fatmawati (2020), who noted that interactive and easy-to-use digital learning tools improve student engagement and learning effectiveness. The positive feedback from both instructors and students suggests that the e-atlas effectively facilitates students' understanding of laboratory procedures. Furthermore, Renggani et al. (2023) emphasize that the practicality of learning media is strongly influenced by its design, clear navigation, and its ability to convey learning messages effectively.

Despite the very high practicality scores (approaching 100%), these results warrant critical evaluation. The small sample size (7 students in the small group trial and 25 students in the large group trial) may have led to an overestimation of the e-atlas's practicality. Future studies should include a larger and more diverse group of students to obtain a more accurate assessment of its practicality across various learning contexts. Additionally, as the students involved in this trial had prior experience with laboratory procedures (having completed the Biology Laboratory Knowledge course), their evaluation of the e-atlas may have been influenced by this familiarity. Future research should involve students with varying levels of experience to assess the tool's effectiveness more comprehensively.

The e-atlas's design and interactivity are key strengths that contribute to its high practicality scores. By integrating QR codes, the e-atlas provides on-demand access to instructional materials, promoting self-directed learning. This aligns with the findings of Harahap & Siahaan (2020), who emphasized that technology-based learning tools offer easy access and flexibility, enabling students to control their learning process according to their individual needs and pace.

Overall, the e-atlas represents a significant advancement in biology laboratory learning. Its validity, confirmed by expert evaluations, and practicality, demonstrated through trials with both instructors and students, indicate that it is a valuable and feasible tool for supporting laboratory learning. However, as with any educational tool, continuous testing and refinement are necessary, particularly with a more diverse user group, to minimize potential biases and improve its applicability across different educational settings.

Conclusions

This This study developed an e-atlas for biology laboratory equipment work instructions using the 4D model up to the development stage, incorporating a QR code for easy access. The e-atlas achieved high validity (97.5%) and practicality

(91.32%), demonstrating its user-friendliness, effectiveness in enhancing understanding of work procedures, and suitability for use in biology laboratory practicums. These results highlight its potential as an innovative digital learning resource in higher education. The e-atlas supports independent, technology-based learning, particularly in laboratory courses.

Future research should focus on evaluating the effectiveness of the e-atlas in real-world educational settings. Specifically, studies could assess its impact on student learning outcomes, engagement, and retention in laboratory practices, as well as examine its performance across diverse student populations and learning environments.

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