

QR code-based booklet on walikukun leaf antibacterial activity for community science education

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Abstract: Limited public knowledge of local biological potential highlights the need for concise, contextual, and accessible science education media. This study developed and formatively evaluated a QR Code-based booklet on the antibacterial activity of walikukun leaves (*Schoutenia ovata* Korth.) for community science education. An adapted ADDIE framework was used through analysis, design, development, and formative evaluation; the study did not proceed to full-scale implementation. The needs analysis involved 56 respondents, and the prototype was validated by three material experts and three media experts. A formative readability and initial effectiveness trial involved 30 community members using a one-group pretest-posttest design. Data were analyzed descriptively and with the Wilcoxon signed-rank test and effect size. Results showed that 64.3% of respondents were unfamiliar with walikukun and its leaf benefits, while 91.1% were unfamiliar with pathogenic bacteria; all respondents supported booklet development. Expert validation indicated very high feasibility for material (94.5%) and media (91.8%), and user readability and response reached 95.5%. Mean knowledge scores increased from 1.93 to 4.00 ($Z = -4.300$, $p < 0.001$, $r = 0.785$). The booklet was therefore highly feasible and readable and showed promising initial effectiveness in a formative community trial.

Keywords: Antibacterial activity, community science education, local potential

Abstrak: Terbatasnya pengetahuan masyarakat tentang potensi hayati lokal menunjukkan perlunya media pendidikan sains yang ringkas, kontekstual, dan mudah diakses. Penelitian ini mengembangkan dan mengevaluasi secara formatif buklet berbasis Kode QR tentang aktivitas antibakteri daun walikukun (*Schoutenia ovata* Korth.) untuk pendidikan sains masyarakat. Kerangka ADDIE diadaptasi melalui tahap analisis, desain, pengembangan, dan evaluasi formatif; penelitian belum sampai pada implementasi skala luas. Analisis kebutuhan melibatkan 56 responden, sedangkan prototipe divalidasi oleh tiga ahli materi dan tiga ahli media. Uji formatif keterbacaan dan efektivitas awal melibatkan 30 anggota masyarakat dengan desain pretest-posttest satu kelompok. Data dianalisis secara deskriptif serta menggunakan uji Wilcoxon signed-rank dan ukuran efek. Hasil menunjukkan bahwa 64,3% responden belum mengenal walikukun dan manfaat daunnya, sedangkan 91,1% belum mengenal bakteri patogen; seluruh responden mendukung pengembangan buklet. Validasi ahli menunjukkan kelayakan sangat tinggi pada aspek materi (94,5%) dan media (91,8%), sedangkan keterbacaan dan respons pengguna mencapai 95,5%. Rerata skor pengetahuan meningkat dari 1,93 menjadi 4,00 ($Z = -4,300$; $p < 0,001$; $r = 0,785$). Dengan demikian, buklet sangat layak dan mudah dipahami serta menunjukkan efektivitas awal yang menjanjikan dalam uji formatif pada masyarakat.

Kata kunci: Aktivitas antibakteri, pendidikan sains berbasis masyarakat, potensi lokal

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INTRODUCTION

Laboratory research on the antibacterial activity of local plants can generate valuable scientific information, but such findings are not always easily understood by the general public. This condition is particularly relevant to walikukun (*Schoutenia ovata* Korth.), a plant associated with the Walikukun Hills and Dadi Temple areas of Tulungagung Regency. Previous research has reported antibacterial and antioxidant activity in *S. ovata* extract,

while laboratory research underlying the present study has also demonstrated antibacterial activity of walikukun leaf extract against several pathogenic bacteria (Palupi & Agusta, 2021). However, laboratory findings are limited to in vitro evidence and cannot directly be interpreted as evidence that walikukun leaves can replace antibiotics or be used as a medical treatment. The problem, therefore, is not only the availability of scientific findings but also the gap between locally produced laboratory evidence and the public's ability to understand and interpret such information appropriately.

This gap highlights the importance of science communication that can translate scientific concepts into information that is accurate, concise, and appropriate for non-specialist audiences. Shivni et al. (2021), explain that effective public science communication requires complex scientific information to be transformed into messages that are accurate, understandable, engaging, and suited to the characteristics of the audience. Hutchins (2020) emphasizes that scientific communication should consider the characteristics of the intended audience, the purpose of communication, and the format used to present scientific information, particularly when research findings are communicated to non-expert audiences. Salzmann et al. (2025), further found that simplifying scientific information can improve comprehensibility, although excessive simplification may increase perceived credibility and confidence in evaluating scientific information. The need for accessible and meaningful information is also related to information literacy, which supports people's ability to understand, evaluate, and use information appropriately (Guerola-Navarro et al. 2023). In the context of local biodiversity, science communication is particularly relevant because local plants can connect community knowledge with scientific knowledge and contextual science education. found that integrating local and indigenous knowledge into science learning can increase relevance to the participants' environment and strengthen understanding of the relationship between science and society (Damopolii et al., 2026; Latip et al., 2024; Rahman et al. 2026). Therefore, the results of research on local plants need to be translated into educational media that are accessible to the community while maintaining sufficient scientific context and accuracy.

A booklet is one potential medium for addressing this problem because it can organize scientific information systematically, concisely, and visually, allowing readers to access and review information independently. Previous research has shown that booklets can function as science learning media when their content, presentation, language, and format meet appropriate quality criteria (Andini & Saifuddin., 2023; Hartika et al., 2024). The use of local biological potential in educational media can also make scientific information more contextual and meaningful to users (Rachmawati et al., 2024; Yudhistian & Cintamulya., 2024). Thus, a booklet about walikukun can provide a focused explanation of the plant, pathogenic bacteria, antibacterial activity, laboratory testing, and the interpretation and limitations of in vitro findings without converting preliminary laboratory evidence into therapeutic claims.

The booklet can further be integrated with a Quick Response (QR) code to connect printed information with supplementary digital resources. QR codes enable users to access additional materials such as videos, images, documents, or websites through smartphones, thereby extending the information presented in printed media. A review by Faggiano et al. (2021) of 151 publications found that QR codes have been used for information provision,

education, surveys, and access to multimedia resources in health and educational contexts. Rakha (2025), similarly reported that QR-code integration can provide rapid access to supplementary learning resources and receive positive user responses. However, technology alone does not determine the quality of an educational medium. The content must remain scientifically accurate, while the presentation, language, visual design, readability, and usability need to be evaluated through expert validation and user testing (Putri et al., 2026; Islam et al., 2025). Consequently, the proposed QR code-based booklet is intended to combine the accessibility and independent reading characteristics of a booklet with flexible access to supplementary digital information.

Although previous studies have developed booklets and digital media based on local biodiversity, medicinal plants, and environmental potential, many have been directed toward formal education and student users. Research on local medicinal plants, for example, has commonly positioned the resulting media as biology learning resources, while studies of digital science learning have largely focused on students' learning outcomes and health or science literacy (Jannah et al., 2026; Subianto et al., 2021). Research that specifically translates laboratory findings concerning the antibacterial activity of a locally significant plant into a science education medium for the general public remains limited. This study therefore addresses this gap by developing a QR code-based booklet based on research findings concerning the antibacterial activity of walikukun leaves and positioning the community as users within a non-formal science education context.

Based on this problem and the proposed solution, this research aims to: (1) develop a QR code-based booklet on the antibacterial activity of walikukun leaves as a community science education medium; (2) determine the feasibility of the booklet through material and media expert validation; (3) analyze the readability and public response to the booklet; and (4) examine its initial effectiveness based on changes in public knowledge before and after using the media. The study is expected to contribute to non-formal science education, the dissemination of university research findings to the community, and the contextual use of local biodiversity for science literacy.

METHOD

This research used a research and development (R&D) approach to produce a Quick Response (QR) code-based booklet on the antibacterial activity of walikukun leaves (*Schoutenia ovata* Korth.) for community science education. The ADDIE framework was adapted to the scope of the study (Zakiron et al., 2025). Activities covered analysis, design, prototype development, expert validation, revision, and formative product trials. Because the product was tested with a limited convenience sample and had not yet been disseminated in routine or large-scale settings, the trial was treated as formative evaluation within the development stage rather than full implementation.

To obtain preliminary evidence during formative product evaluation, a one-group pretest-posttest design was used:

$$O_1 \quad X \quad O_2 \quad (1)$$

Description:

O1 = measurement of knowledge before using the booklet;

X = the provision and use of QR code-based booklets; and

O2 = measurement of knowledge after using the booklet.

This design was used to obtain preliminary evidence of changes in knowledge after the use of the booklet. Because it did not involve control groups and randomization of participants, the results were interpreted as preliminary effectiveness and not as definitive evidence of causality. The design of a single group can only show that the changes occurred after the intervention, but it cannot yet confirm that the changes are entirely due to the intervention (Bierer et al., 2025).

The development and testing of the booklet was conducted in July - October 2024 in Tulungagung Regency, East Java, Indonesia. The booklet material was compiled based on the results of laboratory research conducted by researchers on the antibacterial activity of walikukun leaf extract against five pathogenic bacteria, namely *Escherichia coli*, *Salmonella* sp., *Shigella* sp., *Staphylococcus aureus*, and *Vibrio cholerae*. Walikukun was chosen because it is one of the local plants found in the Walikukun Hills area and around Dadi Temple, Tulungagung. The integration of local potential into science education media is intended to connect scientific concepts with the community environment. Previous research has shown that local plants and ethnobotanical knowledge can be developed into contextual sources of biology education (Halhaji & Suryadarma., 2022; Latip et al., 2024).

The research involved three groups of participants according to the stages of development. The needs analysis involved 56 community members aged 18-70 years. Participants were recruited using convenience sampling techniques through the distribution of online questionnaires using Google Forms. The questionnaire link is distributed via WhatsApp, email, and social media. Participants were asked to provide information about: knowledge about walikukun plants; knowledge of the benefits of walikukun leaves; knowledge of pathogenic bacteria; experience using QR code-based booklets; experience using media about the antibacterial activity of walikukun leaves; approval of the development of the booklet; and perceptions of the benefits of booklets to society.

Product validation involves six experts who are purposively selected based on the suitability of their expertise, consisting of: three experts in the fields of biology, microbiology, and plant materials; and three experts in learning media and educational technology. Material experts assess the accuracy of the concept, completeness of content, relevance of research results, up-to-date information, and suitability of scientific language for the community. Media experts assess visual design, typography, layout, display consistency, readability, image quality, ease of use, and QR code functionality.

The initial readability and effectiveness test involved 30 members of the Tulungagung Regency community. Participants were selected using convenience sampling techniques based on their willingness to participate in the entire series of trials and the ability to access the booklet via smartphones or other digital devices. Inclusion criteria include being at least 18 years old, domiciled in Tulungagung Regency, able to read Indonesian, having a device that can access booklets, and willing to participate in all stages of research. Participants who did not complete the pretest, use of a booklet, posttest, or response questionnaire were excluded from the analysis. Trial participants obtained a link or QR code booklet through Google Forms, then were asked to read the booklet and fill in the instruments provided. Before filling out the instrument, participants were provided with an explanation of the objectives, procedures, voluntariness of participation, confidentiality of data, and the right

to opt out. Consent to participation is obtained electronically before participants access the questionnaire.

The analysis stage aims to identify the initial knowledge of the community, information needs, experience using QR code-based media, and acceptance of the booklet development plan. The needs analysis questionnaire consisted of seven closed-ended questions with a choice of “yes” and “no” answers. The results of the analysis are used to determine: the characteristics of the target user; depth and breadth of material; appropriate language for the community; the form of presentation of information; the need for illustration and visualization; and the use of QR codes as a means of access to digital booklets. Needs analysis is placed as the initial stage for the product to be developed based on user knowledge gaps, rather than solely on developer assumptions.

The design stage is carried out by compiling media objectives, content structure, storyboards, visual designs, and forms of digital access. The booklet is designed in A5 format using the Canva app and saved in PDF format. The A5 format was chosen to keep the booklet comfortable to read on digital devices and allow printing if required. The structure of the booklet consists of three main parts:

Table 1. Booklet structure

Sections	Contents
Initial section	Cover, foreword, and table of contents
Core parts	Introduction, the concept of bacteria, antibacterial activity, pathogenic bacteria, five test bacteria, walikukun plants, and results of antibacterial activity of walikukun leaves
The end	Cover, reference list, glossary, and author profile

The material is presented using short sentences, supporting illustrations, and explanations of scientific terms. The booklet asserts that the reported antibacterial activity is the result of in vitro testing and not evidence that walikukun leaves can replace antibiotics or be used directly as a treatment. The finished booklet file is uploaded to digital storage. The access link is then converted into a QR code and placed on the cover. QR code allows users to access the booklet through a smartphone camera. This technology can provide quick access to text, images, and digital materials at a relatively low cost (Faggiano et al., 2021; Rakha, 2025).

At this stage, the initial design is developed into a complete booklet prototype. The prototype is then validated by material experts and media experts. Each expert provides quantitative assessments and qualitative commentary. Subject matter expert input is mainly used for: simplify sentences that are too long; improve the accuracy of biological and microbiological terms; clarify the interpretation of antibacterial activity; complete reference sources; and enlarge unclear images. Media expert input is used to: improve font consistency and font size; distinguish the hierarchy of titles and subheadings; improve color composition; adapt the image to the material; improve the layout; and ensure QR codes can be scanned. The prototype is revised based on the input before being given to the public. This procedure is in line with booklet development research that places format, content, and language validation as the basis for determining product feasibility (Hartika et al., 2024; Putri et al., 2026).

A formative product trial was conducted online with 30 participants. Participants completed a pretest, received the booklet link or QR code, scanned the code and studied the booklet, completed a posttest using the same indicators, and then completed the readability and response questionnaire. Open-ended comments were also collected. This limited trial generated evidence for prototype revision, readability, user acceptance, and initial knowledge change; it was not treated as full-scale implementation.

Formative evaluation was conducted throughout the design and development process through research-team review, expert validation, prototype revision, QR code functionality checks, participant readability responses, and the limited pretest-posttest trial. The evidence was used to determine final revisions required before broader implementation and effectiveness testing.

Four types of instruments were used in the study. The questionnaire consists of seven closed-ended questions with “yes” and “no” answers. The instrument was used to map people’s knowledge and needs for booklets. The subject matter expert validation sheet uses a four-level scale: 1 = very poor; 2 = poor; 3 = good; and 4 = very good. The assessment includes the correctness of the concept, the relevance of the material, systematics, completeness, clarity of language, suitability of illustrations, the use of research results, and the prudence of submitting antibacterial claims. The media expert validation sheet uses the same scale. The aspects assessed included booklet size, layout, color, typography, display consistency, image quality, readability, ease of navigation, quality of digital access, and QR code functionality.

The readability questionnaire assessed: ease of understanding the content; clarity of sentences; legibility of text; image quality; the attractiveness of the appearance; systematics of presentation; ease of accessing QR codes; usefulness of the information; and interest in using or recommending booklets. The questionnaire uses a four-level scale from 1 = very poor to 4 = very good and features an open-ended comment column. Knowledge tests are used before and after participants study the booklet. The test measures a basic understanding of: walikukun plants; pathogenic bacteria; definition of antibacterial activity; antibacterial potential of the walikukun leaves; and the limits of interpretation of laboratory research results. The total score in the research data is in the range of 0 - 4. The same scoring instruments and procedures are used in the pretest and posttest so that the scores of the two measurements can be compared in pairs.

The answers to the needs analysis questionnaire were analyzed using frequency and percentage:

$$P = (f / N) \times 100\% \quad (2)$$

P as a percentage, f as the number of answers in a category, and N as the number of participants. The scores of material experts, media experts, and the public as a feasibility analysis are calculated using the average:

$$\bar{x} = \Sigma X / n \quad (3)$$

$\bar{X}$ is the mean score, ΣX is the sum of all observed scores, and n is the number of observations. The mean was categorized using four equal-width intervals:

Table 2. Score ranges and feasibility categories

Score range	Category
3.26–4.00	Highly feasible
2.51–3.25	Feasible
1.76–2.50	Less feasible
1.00–1.75	Not feasible

Note. Categories were derived by dividing the 1.00-4.00 response scale into four equal intervals (interval width = 0.75); classification developed by the authors.

As an additional analysis, scores can be converted to eligibility percentages:

$$P = (\Sigma X / \Sigma X_{\max}) \times 100\% \quad (4)$$

Comments and suggestions from experts and users are analyzed descriptively by grouping them into aspects of content, language, visuals, readability, and QR code functionality. The results of the qualitative analysis are used to determine the revision of the product.

The initial and final knowledge scores were analyzed descriptively using the number of participants, average, standard deviation, minimum values, and maximum. The normality of the distribution of scores and the difference scores were examined using the Shapiro-Wilk test because the number of participants was 30 people. The comparison test was conducted using the Wilcoxon signed-rank test. The significance level is set at $\alpha=0.05$. The statistical hypothesis is formulated as follows:

$$H_0: \text{median}(D) = 0; \quad H_1: \text{median}(D) \neq 0 \quad (5)$$

D is the paired difference between posttest and pretest scores. In addition to significance values, the magnitude of the Wilcoxon effect is calculated using:

$$r = |Z| / \sqrt{N} \quad (6)$$

Z as Wilcoxon's standard statistic and N as the number of measurement pairs. The r-value is interpreted as a small effect of about 0.10, medium around 0.30, and large ≥ 0.50 . Effect size reporting is important because significance values only indicate the existence of differences, whereas effect sizes provide information about the magnitude of the change (Peres, 2026).

RESULTS AND DISCUSSION

Community need for local potential-based science information

The needs analysis involved 56 community members. The results show that the public's initial knowledge about the walikukun plant, the benefits of walikukun leaves, and pathogenic bacteria is still limited. A total of 36 participants (64.3%) did not know the Walikukun plant and the benefits of its leaves. Knowledge of pathogenic bacteria is also relatively low; Only five participants (8.9%) said they knew about it. Most of the participants have never known QR code-based booklets as a source of information. None of the participants had ever used a QR code-based booklet that specifically discussed the

antibacterial activity of walikukun leaves. On the contrary, all participants expressed their agreement with the development of the media and assessed that the booklet would be beneficial to the community.

Table 3. Results of community needs analysis

No.	Indicator	Yes, n (%)	No, n (%)
1	Knowing the walikukun plant	20 (35.7)	36 (64.3)
2	Knowing the benefits of walikukun leaves	20 (35.7)	36 (64.3)
3	Knowing pathogenic bacteria	5 (8.9)	51 (91.1)
4	Knowing QR Code-based booklets as a source of information	22 (39.3)	34 (60.7)
5	Have used a QR Code booklet about the antibacterial activity of walikukun leaves	0 (0.0)	56 (100.0)
6	Approve the development of a QR Code-based booklet	56 (100.0)	0 (0.0)
7	Assessing the development of booklets would be beneficial	56 (100.0)	0 (0.0)

The findings show that there is a gap between the potential of walikukun as a local biological resource and public knowledge of the plant. These results became the basis for the development of a booklet that emphasized the introduction to walikukun, the concept of pathogenic bacteria, antibacterial activity, and the interpretation of laboratory research results.

The needs analysis showed that most of the participants did not know the walikukun plant, the benefits of its leaves, and the concept of pathogenic bacteria. As many as 64.3% of participants did not know the walikukun plant and the benefits of its leaves, while 91.1% did not know pathogenic bacteria. These findings show the gap between the existence of walikukun as a local biological resource and public knowledge about its biological potential. The gap confirms that geographical proximity to a biological resource is not always followed by a scientific understanding of its characteristics and potential.

The low knowledge of the community also shows the importance of science education outside of formal educational institutions. Community science literacy is not only related to the mastery of facts, but also the ability to understand terms, principles, scientific processes, and the relationship between science and social life. Liu et al. (2024), explains that civic scientific literacy includes understanding scientific terminology and principles, scientific methods, and the impact of science on society. Thus, the media about the antibacterial activity of walikukun leaves needs to help the public understand not only that an extract has antibacterial activity, but also how it is tested and what the limits of interpretation are.

This need is consistent with the development of science communication which increasingly places the public as active users of scientific information. Shivni et al. (2021), emphasizing the need to translate scientific knowledge into an accurate, concise, and appropriate message to the characteristics of the audience. Science communication also needs to use a variety of media in order to reach community groups with different learning habits. Phogat et al. found that the use of digital media and devices in science communication is growing rapidly, but research on the effectiveness of digital outreach

strategies in non-Western countries is still limited (Phogat et al., 2025). Therefore, the development of the walikukun booklet provides a contextual contribution to science communication based on Indonesia's local potential.

All participants of the needs analysis agreed to the development of the booklet and assessed that the media would be useful. This initial acceptance shows a latent need for scientific information that is close to people's lives. However, approval of the media cannot be equated with science literacy. Guerola-Navarro et al. show that access to information needs to be accompanied by media and information competence so that people can understand and use information meaningfully (Guerola-Navarro et al., 2023). Therefore, the booklet needs to contain an explanation of the research evidence, the limits of generalization, and the difference between the potential of in vitro antibacterial and clinical effectiveness.

QR code-based booklet design and product

The design stage resulted in an A5-sized digital booklet design developed using the Canva app and saved in PDF format. The product is designed to be readable on a smartphone, laptop, or computer. The link to the booklet is then converted into a QR code and placed on the front and back covers. The final product consists of three main parts. The initial section includes a cover, foreword, and table of contents. The core part includes the definition of bacteria, antibacterial activity, pathogenic bacteria, five types of test bacteria, characteristics of walikukun plants, and the results of research on the antibacterial activity of walikukun leaves. The final section includes the cover, reference list, glossary, and author profile.

Table 4. QR code-based booklet structure

Sections	Material
Beginning	Cover, foreword, and table of contents
Basic materials	Definition of bacteria and antibacterial activity
Pathogenic bacteria	<i>Staphylococcus aureus</i> , <i>Escherichia coli</i> , <i>Salmonella</i> sp., <i>Vibrio cholerae</i> , and <i>Shigella</i> sp.
Local potential	Morphology, distribution, and characteristics of walikukun leaves
Research results	Antibacterial activity of walikukun leaves against pathogenic bacteria
End	Cover, reference list, glossary, and author profile

The booklet uses a combination of dark green, light green, and ivory yellow colors to represent plant and environmental material. Information is presented using short sentences and supporting illustrations. Scientific terms that are thought to be unknown to the public are described in texts or glossaries.

The use of walikukun as the primary material for the booklet extends the role of local biodiversity beyond its function as a research object to become a source of community-based education. Ethnobotanical research demonstrates that local plants can serve as a bridge between biological concepts, community life experiences, cultural knowledge, and environmental conditions. Medicinal plants utilized by the Serawai community have considerable potential to be developed as learning resources for biology education (Halhaji

& Suryadarma, 2022). In addition, the diversity of phytochemical compounds found in medicinal plants traditionally utilized by local communities in Indonesia further highlights their potential as a source of scientific and educational information (Nugraha et al., 2022).

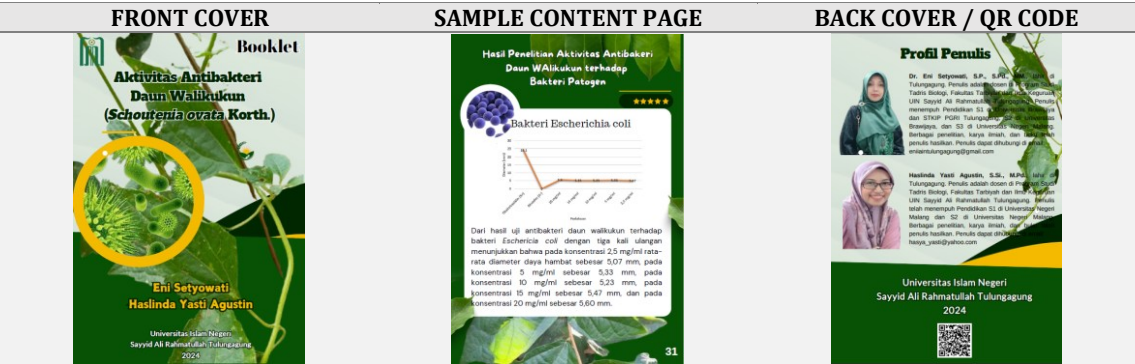


Fig. 1. Product display: front cover, representative content page, and back cover with QR Code

The integration of local potential into science education can make the material more contextual. The local and indigenous knowledge helps participants understand the regional context, connect community knowledge with scientific knowledge, and increase environmental awareness (Latip et al. 2024; Silahooy et al., 2024) . However, such integration needs to be done with scientific reconstruction so that local knowledge is not positioned as a claim that is automatically true without testing.

In this study, the findings on the antibacterial activity of walikukun leaves served as the primary content of the booklet. The use of research findings as the main content of educational media is relevant to previous studies demonstrating that information derived from local plant research can be developed into concise, systematic, and contextualized learning media. Booklets developed from medicinal plant inventories and plant-based research have been shown to be suitable for presenting scientific information in an accessible format while supporting students' understanding of biological concepts. This approach is also consistent with the development of booklets on *Hyphaene thebaica* fruit and Dayak mustard, which demonstrate the potential of local plant information to be transformed into contextual learning media (Panjaitan et al., 2022).

However, antibacterial activity material is related to health information so it requires higher caution than descriptive biodiversity material. The booklet should consistently distinguish between the activity of inhibiting bacterial growth in the laboratory and the safety or effectiveness of use in humans. Simplification of language should not change the level of strength of the evidence. Even et al. (2025), placing accuracy, source transparency, fit with audience, accessibility, and clarity of message as important criteria in evaluating public science communication media. Thus, the development of the walikukun booklet needs to be seen as an educational medium and dissemination of research results, not as a treatment guide.

The QR code is one of the product's main features because it connects people to digital booklets via smartphones. Faggiano et al. (2021), through a review of 151 articles, it was found that QR codes are used to provide information, collect data, support education, and

connect users with multimedia materialst. This technology is easy to create, low-cost, and accessible with smartphone cameras.

Rakha (2025), indicates that the use of QR codes can speed up access to videos, diagrams, instructions, and learning resources. Its integration into learning results in increased knowledge and positive responses, especially when QR codes become part of the learning design, rather than just an additional link. Uçak and Usta (2022), also found that learners and parents responded positively to QR code-assisted science materials because the medium facilitated access to additional learning resources. Minard (2024), states that QR codes can enrich the learning experience by connecting text, maps, images, videos, and real-world content.

In this study, QR codes mainly function as an access door to PDF files. These functions are effective in reducing technical barriers, but they have not yet fully utilized the capacity of QR codes to provide multimedia experiences. Subsequent development may relate specific sections to videos of the research process, animations of antibacterial mechanisms, morphological photos of walikukun, explanatory audio, or formative quizzes. However, adding content needs to consider the file size, link stability, internet data needs, site security, and the user's digital capabilities. The QR code should also be accompanied by a written link address so that the media can still be accessed if the scan fails.

Expert validation and product revision

The validation of the material was carried out by three biologists. The results of the assessment showed an average score of 3.78 out of a maximum score of 4.00. The score is equivalent to an achievement rate of 94.5% and belongs to the very feasible category. The material expert stated that the contents of the booklet were in accordance with the concept of antibacterial activity and the material of the walikukun plant. However, some sentences are considered too long so they need to be summarized. Experts also suggest that some images be enlarged so that biological objects can be observed more clearly.

Media validation was carried out by three learning media experts. The average score obtained is 3.67 or equivalent to 91.8% of the maximum score. The results put the booklet in a highly feasible category. The main improvements recommended by media experts have to do with typographic consistency and image suitability. The font size in the heading, subheading, and body text needs to be consistently differentiated to make the information hierarchy clearer. Some illustrations also need to be adapted to the accompanying material.

Table 5. Product feasibility results

Assessment groups	Number of assessors	Average score	Percentage equivalence	Category
Material Expert	3	3.78	94.5%	Highly feasible
Media Expert	3	3.67	91.8%	Highly feasible
Community/user	30	3.82	95.5%	Highly feasible

Product revision

Prototype revision is carried out based on input from material experts and media experts. A summary of product changes is presented in Table 6.

Table 6. Revision of the booklet based on expert validation results

Sources of feedback	Problems found	Revisions made
Material Expert	Some sentences are too long	Sentences summarized and simplified
Material Expert	Some images are too small	Image enlarged and clarified
Media Expert	Font size is not consistent	Font size hierarchy of titles, subheadings, and text improved
Media Expert	Some images don't fit the material	Images replaced or customized
Media Expert	The view between chapters is not completely consistent	Colors, margins, and layouts are standardized

After revision, the QR code was re-tested on mobile devices. The revised prototype was then used in the formative product trial. The material validation score of 3.78 out of 4.00 indicates that the expert rated the booklet's content to be very feasible. This high score indicates that the material has met the aspects of conceptual accuracy, content relevance, systematics, language, and suitability with the research results. These results are in line with research of Hartika et al. (2024), which obtained high validity in the booklet of the enriched reproductive system as a result of the inventory of local medicinal plants. The research shows that integrating the results of field research into booklets can produce accurate learning resources if format, content, and language are systematically validated.

The results of this study are also consistent with Jannah et al. (2026), which reported an Aiken's V value of 0.95 for a booklet on biodiversity utilization based on galactagogue plant inventory. The highest validity was found in the content aspect, while the performance obtained a comparatively lower value. The pattern shows that the truth of the material and the visual quality are two different dimensions that need to be evaluated separately. Putri et al. (2026), it also found that traditional medicinal plant booklets can be declared viable after going through validation of content, format, language, and reliability assessments between validators.

Media validation resulted in a score of 3.67, equivalent to 91.8%, which falls within the very feasible category. This score indicates that the layout, color scheme, typography, illustrations, accessibility, and overall functionality of the QR code meet the established criteria for media development. These findings are consistent with previous research reporting excellent evaluations of digital booklets by subject matter experts, media experts, teachers, and users (Andini & Saifuddin., 2023; Ivaningtias et al., 2024). The findings further confirm that digital booklets should maintain a balance between content quality and visual appeal to support their effectiveness as learning media.

Validators' comments regarding sentences that are too long, images that need to be enlarged, and inconsistencies in font size indicate that expert validation not only serves to determine eligibility categories, but also improves the quality of communication. Shiyamsyah et al. (2024) found that presentation, content, layout, text, and language are interrelated components in determining the validity of biology teaching materials. Clear language and consistent layout help users follow the structure of information more easily. Validation of biodiversity e-books by Ivaningtias et al. (2024), also shows that the

integration of content, activities, visuals, and user needs needs to be checked before the product is used at the implementation stage.

Although the validation score is high, the use of three subject-matter experts and three media experts has its limitations. With a small number of validators, the average score can be affected by a single assessment. Subsequent research should report content validity using Aiken's V or the content validity index and include the coefficient of agreement among validators. This will reinforce the evidence that high scores reflect not only the average score but also the consistency of experts' assessments.

Readability and user acceptance

The readability test and response to the booklet involved 30 community members. The average score obtained is 3.82 out of a maximum score of 4.00 or equivalent to 95.5%. These results are in the very feasible category. User ratings show that the contents of the booklet are easy to understand, the media display is attractive, the size and font are readable, and the QR code makes it easy to access the product. Thus, the booklet meets the criteria for readability and user acceptance to be applied as a community science education medium.

A readability score of 3.82, or 95.5%, indicates that people consider booklets very easy to use and understand. The user's score is even higher than those of material and media experts. The difference can arise because experts evaluate products against technical standards, whereas people assess the user experience directly. The high user acceptance indicates that the simplification of language, image selection, material structure, and access via QR codes aligns with the community's initial needs.

The findings are consistent with Andini and Saifuddin (2023), which obtained a user response of 94.89% to the digital booklet. Booklets that combine concise text and attractive images are considered to be able to help users understand complex biological material. Putri et al. (2026) It also explains that booklets have the potential to increase interest because they present the material in a concise, clear, and well-supported way, with relevant illustrations. These results are also in line with research of Yudhistian and Cintamulya (2024), which shows that digital biological media based on local potential obtains a very strong user response. Contextual media is considered to help users connect the material to objects found in the surrounding environment. Rachmawati et al. (2024) reported that the development of mangrove diversity e-modules based on local potential also produces viable products and supports environmental attitudes.

However, very high acceptance scores also require critical review. Participants may give a positive assessment because the media is new, interesting, and they have never used it before. In addition, collecting responses through Google Forms can cause selection bias because it is easier to reach people who are used to using smartphones. Therefore, subsequent research needs to involve users across a wider range of ages, education levels, occupations, reading abilities, and technology experience. Objective readability testing, such as reading duration, QR code scanning success, navigation errors, and comprehension of terms, also needs to be added.

Formative effectiveness trial

The initial effectiveness of the booklet was analyzed based on the knowledge scores of 30 participants before and after using the media. Before using the booklet, the average knowledge score was 1.93 with a standard deviation of 1.507. After using the booklet, all participants obtained a score of 4.00 so that the standard deviation of the posttest score was 0.000.

Table 7. Descriptive statistics of community knowledge

Measurement	N	Average	SD	Minimum	Maximum
Pretest	30	1.93	1.507	0	4
Posttest	30	4.00	0.000	4	4
Score changes	30	2.07	-	0	4

Descriptively, there was an average increase of 2.07 points in the score range of 0 - 4. Posttest scores that all reach the maximum score indicate an increase in knowledge, but also indicate a possible ceiling effect because the instrument cannot distinguish the level of knowledge of participants once they have reached the maximum score.

The normality test shows that the pretest score is not normally distributed. The significance values of Kolmogorov–Smirnov and Shapiro–Wilk are both smaller than 0.001. Posttest scores cannot be tested for normality because all participants get the same score.

Table 8. Normality test results

Variable	Kolmogorov-Smirnov	p	Shapiro-Wilk	p	Conclusion
Pretest	0.399	<0.001	0.682	<0.001	Non-normal
Posttest	0.399	<0.001	0.682	<0.001	Non-normal

Based on Table 8, the normality test results indicate that both the pretest and posttest scores were not normally distributed. The Kolmogorov–Smirnov test produced a significance value of less than 0.001 for both the pretest and posttest scores, while the Shapiro–Wilk test also yielded a significance value of less than 0.001. Since both significance values are below 0.05, the normality assumption was not met for the pretest and posttest data. Therefore, the comparison between pretest and posttest scores was analyzed using the Wilcoxon signed-rank test, which is a non-parametric test appropriate for paired data when the normality assumption is not satisfied. The ranking results showed that 20 participants experienced an increase in posttest scores compared with their pretest scores, 10 participants had unchanged scores, and none experienced a decrease in scores.

Table 9. Stages of change in knowledge score

Score changes	N	Average rating	Number of ratings
Posttest < pretest	0	0.00	0.00
Posttest > pretest	20	10.50	210.00
Posttest = pretest	10	-	-
Total	30	-	-

The Wilcoxon test yielded $Z = -4.300$ with $p < 0.001$. Thus, there was a significant difference between the public's knowledge score before and after using QR code-based booklets.

Table 10. Results of the booklet's initial effectiveness test

Comparison		Z	p	Effect size (r)	Interpretation
Posttest pretest	-	-4.300	<0.001	0.785	Large

The effect size is calculated using the formula:

$$r = |-4.300| / \sqrt{30} = 0.785 \quad (7)$$

The value $r = 0.785$ indicates a large effect size. Thus, the use of QR code-based booklets is followed by a statistically significant and practically large increase in public knowledge. Overall, the research resulted in a QR code-based booklet that met three main criteria, namely validity, readability, and initial effectiveness.

Table 11. Summary of product evaluation results

Criteria	Indicator	Results	Conclusion
Validity of the material	Evaluation of three subject matter experts	3.78/4.00	Highly feasible
Media validity	Rating of three media members	3.67/4.00	Highly feasible
Readability	30 user ratings	3.82/4.00	Highly feasible
Knowledge changes	Pretest 1.93 to posttest 4.00	($p < 0.001$)	Significant
Magnitude of change	Wilcoxon effect size	($r = 0.785$)	Large effect

The results show that the QR code-based booklet on the antibacterial activity of walikukun leaves has excellent validity and readability and shows its initial effectiveness in increasing public knowledge. However, the effectiveness findings need to be interpreted within the design limits of one group without control and the presence of uniform posttest scores at maximum values.

The average knowledge score increased from 1.93 to 4.00. The Wilcoxon test showed significant differences with $Z = -4.300$, $p < 0.001$, and effect size $r = 0.785$. These values show a large effect. Twenty participants experienced an increase, ten participants obtained the same score, and no participants experienced a decrease. The increase can be explained by several characteristics of the media. First, the content of the booklet directly answers the knowledge gaps found in the needs analysis. Second, the material is presented in stages starting from the concept of bacteria to the results of antibacterial research. Third, concise text and illustrations reduce the burden of information processing. Fourth, access through smartphones allows participants to read the material independently and repeatedly.

These findings are consistent with digital media research based on local potential. Kamila et al. (2025), found that science e-books that integrate local potential through PBL-ESD improve users' science literacy. Islam et al. (2025), also reported that e-books that integrate local environmental problems can improve science competence because participants connect concepts with real problems in their areas. Fajeriadi et al. (2025), through the synthesis of local potential-based biology learning research, it shows a tendency to have a positive influence on learning outcomes and attitudes, although the effect size has not always been adequately reported.

Knowledge enhancement is also in line with technology-based science media research. Subiantoro et al. (2021), shows that e-learning based on socioscientific issues can be a framework for developing health literacy if materials, learning flows, and digital elements are designed in an integrated manner. Diharjo et al. (2025), also reports that interactive media based on socioscientific issues help to link biological concepts to social problems that require evidence-based understanding. Review of Sari et al. (2025), shows that ethnoscience-based learning generally has a positive influence on science literacy because it increases the relevance of the material and connects local knowledge with scientific explanations.

More broadly, these results are in line with evidence that media literacy and digital education interventions can improve knowledge. Meta-analysis of Cho et al. (2025), of the 160 media literacy interventions, the effect was positive overall, although the magnitude of the effect varied based on design, user characteristics, duration, and type. It also found that digital education interventions generally improve knowledge and competence, but the quality of the evidence is strongly influenced by the validity of the instrument and the strength of the evaluation design.

The effect size of 0.785 indicates that the change in score is not only statistically significant, but also large practically. Reporting the size of the effect is a strength because the p-value does not provide information about the magnitude of the change. Peres (2026), asserts that nonparametric analyses, including Wilcoxon, need to be equipped with effect measures in order for the practical relevance of findings to be assessed. Nevertheless, all participants obtained a maximum score of 4.00 in the posttest with a standard deviation of 0.00. This condition shows a ceiling effect. Instruments that are too easy or the score range is too narrow to distinguish between participants with medium and high levels of mastery. Staus et al. (2021), explained that the ceiling effect limits the sensitivity of the measurement and can cause the effectiveness of the intervention to appear very high because the instrument does not provide enough room for score variation.

Ten participants who had the same score on the pretest and posttest likely obtained the maximum score from the start. For those participants, the absence of an increase does not necessarily mean that the booklet is not useful; instruments do not allow them to obtain higher scores. On the other hand, the achievement of the maximum score by all participants also does not prove that all participants have an in-depth understanding or are able to evaluate scientific claims. In advanced research, the test needs to be expanded with more items and tiered difficulty levels. In addition to factual knowledge, instruments should measure the ability to: distinguish between *in vitro* evidence and clinical evidence; interpret the data of the inhibition zone; recognize research limitations; evaluate claims of the use of

plants as medicines; identify reliable sources of information; and apply information for secure decision-making.

Although the results of the pretest showed strong changes, the design of a single group without control cannot rule out alternative explanations. Improvement can be influenced by the repetition of the test, the participant's attention to the topic under research, access to other sources of information, or the desire to provide answers that are considered to be in line with the researcher's expectations. Aassert that the design of one pretest–posttest group only shows changes after the intervention, but cannot prove that the intervention is the sole cause of the change (Bierer et al., 2025). Therefore, the term “initial effectiveness” used in this study is appropriate. Stronger claims require quasi-experimental design with a comparator group or controlled randomized trial.

Measurements were also taken as soon as participants read the booklet so it was not yet known whether knowledge lasted for a certain period of time. Further research needs to add a delayed posttest, for example two or four weeks after the intervention. Retention assessments are important because momentary increases can reflect short-term memory, not stable learning.

CONCLUSION

This study produced a QR code-based booklet on the antibacterial activity of walikukun leaves (*Schoutenia ovata* Korth.) as a medium for community science education. In line with the research aims, the booklet was judged highly feasible by both material experts and media experts, and it was rated highly readable with a positive response from community users. The formative trial further showed a promising initial increase in participants' knowledge after using the booklet. These findings indicate that the booklet is feasible, readable, and promising as a medium for disseminating research on local biological potential. Nevertheless, the result represents preliminary formative evidence rather than full implementation effectiveness because the study used a single group, a limited convenience sample, an immediate posttest, and an instrument with a possible ceiling effect. Further research should employ more sensitive measures, diverse samples, a comparison group, and delayed posttests before broader implementation.

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