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Journal of Current Studies in SDGs
Homepage : https://journal.i-ros.org/index.php/JOCSIS
Email : jocsis@i-ros.org

e-ISSN 3089-7564
Vol.3, No.2, June 2027

Development of a Guided Inquiry-Based Biology Practicum Guidebook Integrating Scientific Literacy in Support of SDG 4: Quality Education

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DOI : https://doi.org/10.63230/jocsis.3.2.174

Sections Info

Article history:
Submitted: February 24, 2026
Final Revised: April 4, 2026
Accepted: June 9, 2026
First Available Online: July 19, 2026
Publication Date: June 27, 2027

Keywords:
Biology Practicum;
Guided Inquiry;
Practicum Guidebook;
Scientific Literacy;
SDGs 4.

ABSTRACT

Objective: *To develop and evaluate the feasibility and practicality of a guided inquiry-based biology practicum guidebook integrating scientific literacy for Grade XI high school students. The guidebook was designed to support structured laboratory learning and contribute, at the instructional-resource level, to Sustainable Development Goal 4 by providing a quality learning resource for biology education.* ***Method:*** *Employed a research and development approach using the 4-D model modified into three stages: define, design, and develop. Data were collected through interviews, needs-analysis questionnaires, expert validation, and limited-scale trials. The developed product was assessed by material and media experts and evaluated using response questionnaires completed by two biology teachers and participating students. The quantitative data were analyzed using descriptive percentage analysis.* ***Results:*** *The material expert validation produced an average score of 98.66%, while the media expert validation reached 98%, with both categorized as very good. Teacher responses yielded an average practicality score of 93.52%, whereas student responses reached 84.53%, also within the very good category. These findings demonstrate that the guidebook is highly feasible and practical as a supporting resource for biology practicum activities.* ***Novelty:*** *To integrate guided inquiry stages, laboratory procedures, safety guidance, reporting formats, and scientific literacy tasks within a single practicum guidebook aligned with Phase F biology learning. This integrated design offers a contextual instructional resource that facilitates active investigation, evidence-based reasoning, and quality science education consistent with SDG 4.*

INTRODUCTION

The development of education in Indonesia has been accompanied by continuous curriculum changes. The dynamic nature of the national curriculum reflects the efforts of educational stakeholders to adapt teaching and learning practices to societal developments and emerging educational demands (Wahjusaputri & Bunyamin, 2022). The curriculum implemented in Indonesia continues the direction of the Merdeka Curriculum, which was introduced as an improvement to the 2013 Curriculum (Efendi & Suastra, 2023). These curriculum changes influence the organization and delivery of subject content, including biology materials that require practical learning activities.

As a branch of science, biology is taught within the framework of the Merdeka Curriculum. Biology learning involves scientific facts, concepts, principles, and processes that require students to solve problems through critical thinking (Mahanal et al., 2017). Therefore, students need an accurate understanding of the biological theories and concepts introduced in classroom instruction. Learning biology involves not only acquiring knowledge about living organisms but also understanding the scientific methods used to investigate biological phenomena (Pantiwati, 2016). Consequently, biology learning cannot be separated from experimentation and laboratory practicum activities.

Practical activities constitute an integral component of biology learning because they provide learning experiences across the cognitive, affective, and psychomotor domains (Aliyah & Puspitasari, 2022). Through practical activities, students can directly examine and verify the concepts they have learned in the classroom by conducting experiments aligned with predetermined learning objectives. However, biology practicum activities can be implemented effectively only when they are supported by adequate facilities and infrastructure (Thair & Treagust, 1997). Biological theories are closely related to phenomena encountered in everyday life; therefore, connecting biological concepts with observable facts can make learning more meaningful and prevent it from becoming merely an exercise in memorization.

Based on interviews conducted with biology teachers at SMA Negeri 1 Karanganyar, the researchers found that no specific instruction book or practicum guidebook was available to support Grade XI biology practicum activities during the odd semester. The practicum instructions used by teachers were primarily derived from textbooks according to the topic being studied, resulting in limited variation in practicum learning activities. Before conducting each practicum, teachers had to prepare their own practicum instructions, student worksheets, and report formats.

During practical activities, students also experienced difficulties in understanding the research procedures presented by the teachers. Inadequate understanding of practicum instructions sometimes caused procedural errors and misunderstandings between students and teachers. The student needs analysis showed an achievement level of 81%, indicating a strong need for a biology practicum guidebook. Moreover, teachers had not administered assessments specifically designed to measure scientific literacy. Existing assessments primarily focused on cognitive, affective, and psychomotor learning outcomes. Therefore, additional exercises and assessments addressing scientific literacy competencies are required.

One instructional resource that can address these problems is a guided inquiry-based biology practicum guidebook integrating scientific literacy. A practicum guidebook is an instructional resource containing laboratory procedures and implementation guidelines that help teachers and students conduct practical activities systematically (Hall & Vardar-Ulu, 2014). Practicum instructions assist teachers in preparing laboratory activities and support students in carrying out experimental procedures appropriately (Lazarowitz, 2013). Therefore, a practicum guidebook plays an essential role in ensuring that laboratory activities are well prepared, coherent, and aligned with learning objectives. Integrating a guided inquiry approach into the guidebook can also make practical activities more focused, conceptual, and student-centered.

Guided inquiry is a learning approach that enables students to discover information and construct knowledge with appropriate assistance from the teacher (Gumilar et al., 2020). Through guided inquiry, students learn to formulate questions, search for relevant information, investigate possible answers, and understand the processes through which scientific explanations are developed. Guided inquiry-based practical activities encourage students to construct cognitive knowledge through direct laboratory investigation (Wahab et al., 2021). Guided inquiry and scientific literacy share similar educational objectives because both require students to think critically, creatively, and logically and to solve problems based on evidence. Therefore, guided inquiry learning has the potential to develop students' scientific literacy through active and structured learning processes (Kahar et al., 2022).

Scientific literacy refers to the capacity to use scientific knowledge, identify scientific questions, and draw conclusions based on facts and empirical evidence to understand

natural phenomena and make informed decisions regarding changes caused by human activities (Arohman, 2017). Integrating scientific literacy into the practicum guidebook can enhance the value of practical activities because scientific literacy is an essential competency that students need to develop. Scientific literacy is also one of the principal learning outcomes expected from science subjects, including biology (Ashari et al., 2023). Therefore, developing a guided inquiry-based biology practicum guidebook integrating scientific literacy is important for providing teachers and students with a structured instructional resource and supporting the advancement of quality biology education.

RESEARCH METHOD

This research is a development research (R&D). This research uses the 4-D model developed by Thiagarajan (1974), which was further modified into 3-D (define, design, develop) due to time and cost constraints. Data collection techniques in this study were interviews, needs questionnaires, validity tests, and limited scale tests. In addition, the research instruments used were interview sheets, student needs questionnaires, expert validation test sheets, teacher response questionnaires, and student response questionnaires. The results of the development stage of the practical guidebook in the form of the draft will then be validated by material experts and media experts. This helpful guidebook will also be tested for its practicality with limited-scale trials by teachers and students. The subjects in this study were biology teachers of class XI SMA Negeri 1 Karanganyar Kebumen named Mrs Ani Mugi Rahayu, S.Pd. and Mr Prasetyo Anggun Pribadi, S.Pd., who acted as expert practitioners. The population and sample of this study are all students of grade XI and seven students of grade XI for limited trials in small groups with a purposive sampling technique. Validation and assessment values in limited-scale trials will be calculated using the following formula.

$$P = \frac{f}{N} \times 100\% \quad (1)$$

Information
P : Percentage figures of questionnaire data
f : Number of scores obtaibed
N : Maximum score

Then, the percentage obtained will be interpreted using the modified criteria from (Thair et al., 1997), in Table 1.

Table 1. Data interpretation

Level of Achievement	Category
81< x ≤ 100%	Very High
61< x ≤ 80%	High
41 < x ≤ 60%	Moderate
21 < x ≤ 40 %	Low
x ≤ 20%	Very Low

RESULTS AND DISCUSSION

Results

Results of practical guidebook format selection

The result of the selection of the format of this practical guidebook is in the form of a draft of the sections of the contents of the biology practical guidebook that will be presented. The preparation of the format of this practical guidebook is based on the analysis that has been carried out at the definition stage. The format of this practical guidebook is adjusted to the needs of students to facilitate the practical learning process. In addition, it is also based on the guided inquiry approach, which is the primary basis for developing this guidebook. The aspect of scientific literacy, which is also presented with a scientific literacy assessment, can help students in training their scientific literacy skills. The format of the practical guidebook can be seen in Table 2.

Table 2. Biology practical handbook format

Books Section	Content Components
Cover	Book title Illustration of Practical Learning Class Level and Semester Author Name
Frontpage	Book Title, Author Name and Institution
Preliminaries (Introduction)	Foreword List of contents
Book Introduction Section	Instructions for use Practical Rules and Regulations Laboratory Safety Guided Inquiry Learning Instructions
Core Section of the Book	Practical Title 1. Orientation 2. Formulating the Problem 3. Hypothesize 4. Data Collection and Hypothesis Testing 5. Practical Activities a. Objective b. Basic theory c. Tools and materials d. Work steps e. Observation result f. Questions for Discussion
End of The Book	6. Science Literasi Bibliograph By Author Profile
Attachment	Appendix 1. Report Format Appendix 2. Assessment Format

Based on Table 2, the developed practicum guidebook contains the essential instructions and components required to support biology practicum activities. The introductory section provides general guidance that teachers and students must follow when using the guidebook during laboratory learning. It also includes practicum rules,

laboratory safety procedures, and explanations of hazard symbols that students need to understand to minimize the risk of accidents during experimental activities. Laboratory safety constitutes a systematic effort to prevent accidents arising from laboratory procedures, materials, equipment, and other practicum-related activities (Sukri et al., 2024). Therefore, the inclusion of safety guidance strengthens the function of the guidebook as a resource that supports the effective and responsible implementation of laboratory learning.

The practicum guidebook also plays an important role in developing students' experimental skills, increasing their motivation to learn biology, introducing scientific approaches, and strengthening their understanding of biological concepts (Murthy et al., 2014). The core section of the guidebook was structured according to a guided inquiry approach, which requires teachers to provide appropriate scaffolding based on students' learning needs. In guided inquiry learning, teachers do not directly provide complete answers but offer instructions, prompts, and guidance that enable students to investigate problems and construct their own understanding (Gök, 2014). Accordingly, the learning sequence presented in the guidebook includes orientation, problem formulation, hypothesis formulation, data collection, hypothesis testing, and the implementation of practical activities.

The practicum activities are systematically arranged according to the standard components of a laboratory guide. These components include a foreword or introduction, table of contents, laboratory regulations, practicum titles, learning objectives, theoretical foundations, tools and materials, working procedures, observation results, practicum reports, and evaluation questions (Islamiati et al., 2020). The systematic organization of these elements is intended to make practicum activities more coherent, comprehensible, and manageable for both teachers and students. Thus, the guidebook does not merely present technical procedures but also provides an instructional framework that supports guided investigation, laboratory safety, and the development of students' scientific competencies.

Eligibility of practical guidebook

The practical guidebook is compiled based on the analysis of the definition stage and the guided inquiry approach, accompanied by scientific literacy content designed using the Canva design application and Microsoft Word 2021. This practical guidebook entitled "Biology Practical Guidebook Based on Guided Inquiry with Scientific Literacy Content" has a dark green background cover colour with the addition of illustrations of practical activities so that the cover of this book is designed with an attractive appearance as a general overview of the contents of the book. According to Hubley (2011), the front cover functions as the first information that will be given to students about the book's contents. This biology practical guidebook, as stated in Table 2, contains content that is divided into several parts, namely: introduction (foreword and table of contents), the initial instructions section of the book (instructions for use, laboratory regulations, laboratory work safety, and guided inquiry learning instructions), the core section of the book (practical learning procedures presented with a guided inquiry approach accompanied by scientific literacy content), the end of the book (bibliography and author profile), and appendices. The appearance of the manual can be seen in Figures 1, 2 and 3.

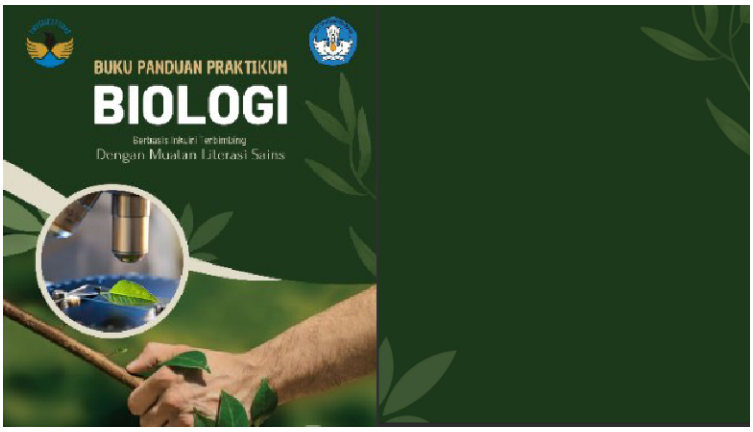

Figure 1. Cover of practical guide book

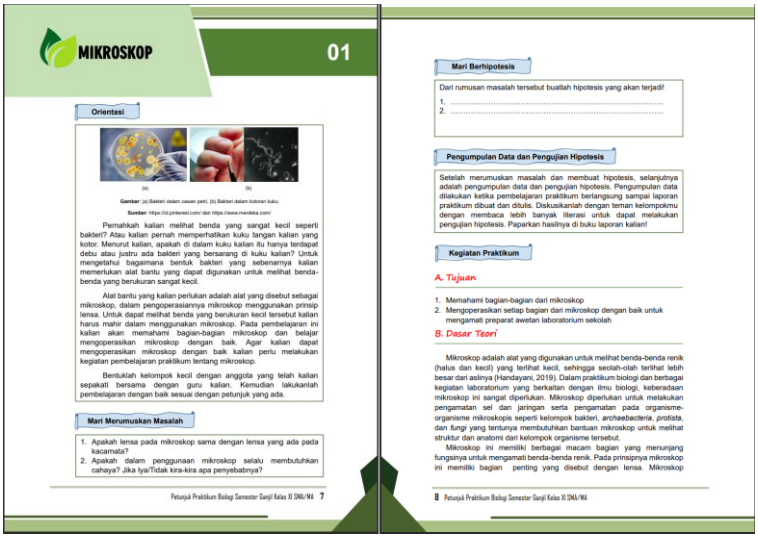

Figure 2. Practical content with guided inquiry approach

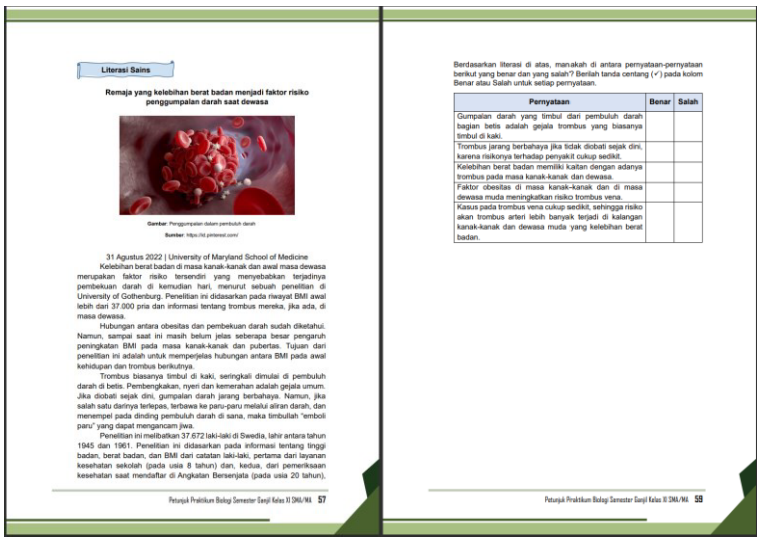

Figure 3. Science literacy content material

The practical guidebook that has been made is then validated by material experts and media experts to determine the feasibility of the practical guidebook as supporting teaching material for useful activities. If there are deficiencies based on suggestions and input from the validator, then this practical guidebook will be revised according to the assessment results from the validation process. Validation was carried out using the

assessment standards for textbooks and enrichment by Balitbang in 2017, which were based on BSNP in 2016 (Gumilar et al., 2020). The results of the validation by material experts can be seen in Table 3.

Table 3. Results of expert validation of material

Assessment Aspects	Total Score	Percentage (%)	Interpretation
Content Eligibility	72	96	Very Good
Presentation Eligibility	30	100	Very Good
Language Eligibility	25	100	Very Good
Average		**98.66**	**Very good**

Based on the data, it can be seen that the average percentage of eligibility in the material aspect of the practical guidebook is 98.88% with very good criteria. The results of the assessment of the material validation concluded that this practical guidebook is very suitable for use, with suggestions and input for improvements in the layout and writing that are adjusted for consistency. The suggestions and input from the material validator are to improve the laboratory work safety material by adding information on handling efforts if exposed to materials with hazard symbols, writing several points in the work steps of the microscope material and adding illustrations to the work steps of the material on the effects of cigarette smoke, adding table captions to specific tables that require, providing image captions and sources for each image in the material that has been presented, and adding attachments to the report format and assessment format sections.

The first aspect in the assessment of the material validator can be seen from the aspect of the feasibility of the content, with a percentage of 96% in the very good criteria. The assessment components in the feasibility of this aspect include suitability with CP (learning achievement), accuracy of material/content, ease and clarity of material/content, suitability of scientific literacy content, and coverage with the guided inquiry approach. The assessment results from the material validator show that the material/content, guided inquiry learning steps, and scientific literacy content presented are appropriate for the relationship of the three aspects with the material presented. This is indicated by the steps of the practicum learning, which begins with the guided inquiry model learning steps, namely orientation, problem formulation, hypothesis, and data collection and testing. This statement is undoubtedly in accordance with Irten et al. (2016) that six stages of learning implementation play a role in the process of improving critical thinking according to the guided inquiry learning model, namely orientation, formulating problems, submitting hypotheses, collecting data, testing hypotheses, and drawing conclusions. In addition, the scientific literacy content presented is also in accordance with the material that is the main topic of discussion in each practicum learning.

The second aspect in the assessment of the material is the feasibility of the presentation aspect of the material, with a percentage of 100% in the very good category. The results of this assessment indicate that the practicum guidebook, which is used as one of the The second aspect concerned the feasibility of the material presentation, which received a score of 100% and was categorized as very good. This result indicates that the practicum guidebook, as a supporting instructional resource for laboratory activities, presents its content coherently, systematically, and consistently. Teaching materials should be organized systematically and designed to meet specific instructional needs so that they can be effectively used by teachers and students during the learning process (Hall &

Vardar-Ulu, 2014). In addition, the developed guidebook includes practicum report and assessment formats that can assist students in documenting experimental results and support teachers in evaluating students' performance after the completion of laboratory activities. Therefore, the material content, practicum procedures, reporting components, and assessment instructions presented in the guidebook can be considered sufficiently comprehensive.

The third aspect concerned language appropriateness, which received a score of 100% and was categorized as very good. This result indicates that the guidebook uses clear, effective, well-structured, and comprehensible Indonesian sentences that minimize ambiguity. Language appropriateness is particularly important in the development of practicum guidebooks because students must accurately understand objectives, theoretical explanations, safety instructions, and experimental procedures. In designing print-based instructional materials, the language should be simple, communicative, and appropriate to the characteristics of the intended users so that the information can be easily understood (Nurlatifah et al., 2022). The maximum score obtained for this aspect therefore confirms that the language used in the guidebook is suitable for supporting students' understanding of both the biological content and the practicum procedures.

The practicum guidebook was also evaluated by a media expert to determine its suitability as a supporting instructional resource for biology practicum activities. Suggestions and comments provided by the media expert were used as the basis for product revision and improvement. The validation instrument was adapted from criteria for evaluating textbooks and enrichment materials, including aspects of book size, cover design, content layout, typography, illustrations, and visual consistency, as referenced in previous textbook evaluation research (Putra & Aman, 2020). The results of the media expert validation are presented in Table 4.

Table 4. Media expert validation results

Assessment Aspects	Total Score	Percentage (%)	Interpretation
Manual Book Size	10	100	Very good
Guidebook Cover Design	30	100	Very good
Design of the Contents of the Guidebook	47	94	Very good
Average		**98**	**Very good**

Based on the data, it can be seen that the average percentage of the suitability of the practical guidebook in the media aspect is 98% with a very good category, so based on the results of the media expert validation assessment, the validator concluded that this practical guidebook is suitable for use with improvements according to suggestions. The suggestions and input from the media validator are improvements to the table of contents to adjust the page numbers with the sub-materials and improvements to the arrangement of the sub-headings so that the presentation of the material is more grouped.

The first aspect of the media expert assessment is the size of the biology practicum guidebook with a percentage of 100% in the very good category. This assessment shows that the size of the practicum guidebook developed is in accordance with the book's content. The size of the practicum guidebook has met ISO standards or international standard paper sizes, namely A4 (210 mm x 297 mm). In addition, the size of the book is also by the content of the practicum guidebook presented, namely, overall, using a font size of 12 for each paragraph of material explanation and systematic learning steps.

The second aspect concerned the cover design of the biology practicum guidebook, which received a score of 100% and was categorized as very good. This result indicates that the layout elements, cover illustrations, font combinations, color composition, book-title color, and title size were harmoniously integrated. Therefore, the guidebook cover was considered visually appealing and capable of attracting students' interest in reading. The cover also serves to represent the content of the guidebook through relevant illustrations, enabling students to identify its main topics before engaging with the material. Students generally show greater interest in instructional materials that combine concise explanations with appropriate images and attractive colors (Hsiao & Shih, 2016). Furthermore, well-designed graphic elements can increase students' motivation and facilitate their understanding of learning materials by helping them visualize the concepts being presented (Safitri & Hartati, 2016).

The third aspect concerned the design of the guidebook's content, which received a score of 94% and was categorized as very good. This finding demonstrates that the internal layout was consistent, proportional, and visually harmonious. The positioning of illustrations, decorative elements, and backgrounds did not interfere with the readability or clarity of the instructional content. In addition, the selected typefaces were legible, appropriately combined with supporting color variations, and free from excessive typographic combinations. Appropriate variations in typography and color can enhance the visual appeal of printed instructional materials when they are applied consistently and do not reduce readability (Zhang, 2018). An attractive textbook design can also motivate students to read and engage with the material, particularly when the illustrations reflect objects or environments that are familiar to them (Fey & Matthes, 2018). Thus, a balanced combination of typography, color, text, and relevant images can strengthen the readability and visual attractiveness of the practicum guidebook.

Limited scale trial

After the product has been validated, the average is calculated, analyzed, and revised; then a limited-scale trial is conducted. This trial was conducted by two biology teachers of SMA Negeri 1 Karanganyar Kebumen and ten students of class XI 6. The instrument used was a teacher response questionnaire for two biology teachers whose results would later be compared to obtain an average of the assessment results of the two teachers. In addition, a student response questionnaire was also given to find out students' opinions regarding the development of a biology practicum guidebook.

The response questionnaire or teacher responses were used to find out the opinions, suggestions and wishes of the two biology teachers at the school so that conclusions could be drawn based on the assessments of the two teachers to determine the practicality of the developed book product. Based on the evaluation of 2 biology teachers at the school, it can be concluded that the biology practicum guidebook developed is very suitable as a teaching material to support biology practicum activities. The results of the teacher's responses can be seen in Tables 5 and 6.

Table 5. Teacher A's response results

Assessment Aspects	Total Score	Percentage (%)	Interpretation
Material/Content	46	92	Very Good
Language	30	100	Very Good
Design and Presentation	43	95.55	Very Good
Average		**95.85**	**Very good**

Table 6. Teacher B's response results

Assessment Aspects	Total Score	Percentage (%)	Interpretation
Material/Content	44	88	Very Good
Language	27	90	Very Good
Design and Presentation	43	95.55	Very Good
Average		**91.2**	**Very good**

Based on the results of the responses from 2 biology teachers at SMA Negeri 1 Karanganyar Kebumen, the average percentage assessment results were 95.85% from teacher A or the first teacher and 91.2% from teacher B or the second teacher, with an average of 93.52% in the very good category. This shows that the biology practicum guidebook that was developed is suitable for use in schools without revision, according to the results of the teacher's assessment. Overall, biology teachers said that the practicum guidebook is ideal for use in schools because it is good enough and in accordance with the needs of students in implementing the independent curriculum in phase F, so it can be used by grade XI students in the odd semester. According to Sfitri et al. (2016), biology learning materials in phase F include cells, the movement of substances through cell membranes, and plant regulation processes. Transport of substance exchange in humans, the body's defence system, human mobility, hormones in human reproduction, and the growth and development of living things.

In addition, students also filled out a questionnaire to determine their responses to the developed practical guidebook. The results of students' responses are only needed as supplementary data and are not the basis for revising the biology practical guidebook. The results of student assessments can be seen in Table 7.

Table 7. Student response results

No	Statement	Percentage (%)	Criteria
1.	The material presented is by the objectives of the practical learning.	88	Very Good
2.	The material presented increased my insight and knowledge.	88	Very Good
3.	The material presented is easy to read and understand.	90	Very Good
4.	The material is presented systematically	80	Good
5.	The images presented are clear and by the material.	92	Very Good
6.	The purpose of the experiment is presented clearly	94	Very Good
7.	The language used in the practical instructions is easy to understand.	86	Very Good
8.	The clarity of the writing made me interested in reading the practical guidebook.	84	Very Good

No	Statement	Percentage (%)	Criteria
9.	The appearance of the practical guidebook attracted my interest in learning.	78	Good
10.	The work procedures presented are detailed and precise.	82	Very Good
11.	This practical guidebook makes practical learning more focused and coherent.	86	Very Good
12.	This practical guidebook makes me more active in doing practicals.	70	Good
13.	This practical guidebook can help me learn independently.	80	Good
14.	This practical guidebook motivates me to do practical learning.	84	Very Good
15.	This practical guidebook can be used as a reference and learning resource.	86	Very Good
	Flat-Flat	84.53	Very Good

Based on the data in Table 4.8, the average percentage value obtained was 84.53%, which is a very good category and is suitable for use as one of the teaching materials, especially in biology practicum learning. The results of student response scores were not optimal because some students felt that the presentation of the practicum guidebook should be more detailed by providing practice questions and pictures of the practicum results. Still, regardless of this opinion, the author has developed the practicum guidebook by the literacy study conducted by the author, so there is no need to add practice questions and pictures of the practicum results to the developed practicum guidebook. This is undoubtedly by Gok et al. (2014), which states that a practicum guidebook consists of topics, objectives, theoretical basis, work steps, tools and materials, observation results and evaluations based on the goals of the practicum. Therefore, the presentation of the practicum guidebook is by the literacy study conducted, and there is no need to add practice questions and pictures of the practicum results. Overall, the responses from students show that this guided inquiry-based biology practicum guidebook with scientific literacy content can be used as supporting teaching materials for practicum activities.

Discussion

The high validation results demonstrate that the developed guidebook has strong content, linguistic, presentational, and visual-design qualities. The material expert score of 98.66% indicates that the biological concepts, guided inquiry stages, and scientific literacy components were considered relevant, accurate, and systematically organized. Similarly, the 98% media-validation score suggests that the guidebook's format, cover, illustrations, typography, and internal layout were appropriate for high school students. Clear language is particularly important in a practicum guidebook because students must interpret procedural instructions accurately to avoid conceptual misunderstandings and errors during laboratory activities (Nurlatifah et al., 2022). Moreover, coherent layouts and relevant visual elements can improve the readability of instructional materials and help direct students' attention toward essential learning information (Fey & Matthes, 2018). These findings indicate that the guidebook meets important characteristics of quality instructional resources and can therefore support the provision of meaningful biology learning experiences associated with SDG 4 (Behnke et al., 2021).

The positive responses from teachers and students further demonstrate the practical value of the guidebook in biology laboratory learning. The teachers' average score of 93.52% indicates that the product is relevant to curriculum requirements, classroom needs, and the implementation of Grade XI practical activities. Meanwhile, the student-response score of 84.53% shows that the guidebook was generally understandable, systematic, and useful for supporting independent learning. Nevertheless, the relatively lower responses regarding students' active participation and the attractiveness of the guidebook indicate that a well-designed learning resource does not automatically guarantee active inquiry. Its effectiveness also depends on teacher facilitation, questioning strategies, group interaction, and opportunities for students to formulate and evaluate evidence-based explanations. Guided inquiry should position students as active investigators while teachers provide appropriate scaffolding during the investigation process (Wahab & Sartika, 2021). This instructional process is essential because guided inquiry and scientific literacy both require students to question phenomena, analyze evidence, and construct logical conclusions (Kahar et al., 2022).

From an SDG perspective, the guidebook contributes primarily to SDG 4: Quality Education by expanding access to a structured, curriculum-aligned, and scientifically oriented learning resource. The integration of scientific literacy tasks allows biology practicum activities to move beyond procedural experimentation toward the interpretation of evidence, evaluation of scientific information, and formulation of conclusions. These competencies are important because biology education should enable students to use scientific knowledge when examining phenomena and addressing problems encountered in everyday life (Ashari et al., 2023). However, the contribution of the product to SDG 4 should be interpreted cautiously because the present study evaluates feasibility and practicality rather than improvements in scientific literacy or learning achievement. Consequently, future studies should employ pre-test and post-test designs, involve broader and more diverse samples, and compare the guidebook with conventional practicum materials. Such research would provide stronger evidence regarding its effectiveness in supporting quality learning outcomes, which constitute a central orientation of SDG 4 (United Nations, 2015).

CONCLUSION

Fundamental Finding : This study successfully developed a guided inquiry-based biology practicum guidebook integrating scientific literacy for Grade XI students. The product demonstrated a high level of feasibility, as indicated by material expert validation of 98.66% and media expert validation of 98%, both of which were categorized as very good. The practicality assessment also produced positive results, with an average teacher-response score of 93.52% and a student-response score of 84.53%. These findings confirm that the guidebook is appropriate as a supporting instructional resource for structured biology practicum activities. By combining guided inquiry stages, laboratory procedures, safety guidance, and scientific literacy tasks, the guidebook provides an integrated learning resource that can support active investigation, evidence-based reasoning, and quality science education in alignment with SDG 4. **Implication :** The developed guidebook can assist teachers in organizing more systematic, coherent, and student-centered practicum activities. It can also help students understand experimental procedures, formulate problems and hypotheses, collect and interpret data, and draw conclusions based on scientific evidence. At the instructional level, the product offers a practical alternative to teacher-prepared worksheets and textbook-based practicum instructions. Its integration of scientific literacy may also encourage biology learning that

goes beyond procedural laboratory work by involving students in critical thinking, scientific communication, and evidence-based decision-making. **Limitation :** This study was limited to the define, design, and develop stages of the 4-D model and did not include the dissemination stage. Product testing was conducted on a limited scale involving only two biology teachers and a small group of Grade XI students from one school. Therefore, the findings primarily demonstrate the guidebook's feasibility and practicality rather than its effectiveness in improving students' scientific literacy, learning achievement, inquiry skills, or long-term retention. The study also did not employ a control group, pre-test and post-test measurements, or classroom observations across multiple practicum topics. **Future Research :** Future studies should implement the guidebook in broader and more diverse educational settings involving larger student samples, multiple schools, and different regional contexts. Experimental or quasi-experimental designs should be used to examine its effectiveness in improving scientific literacy, inquiry skills, conceptual understanding, learning motivation, and laboratory competence. Further research may also compare printed and digital versions of the guidebook, investigate teachers' implementation fidelity, and evaluate students' performance across different biology practicum topics. The dissemination stage of the 4-D model should also be completed to determine the guidebook's scalability, accessibility, and sustainability as a quality instructional resource supporting SDG 4.

AUTHOR CONTRIBUTIONS

Ericka Darmawan contributed to the conceptualization, research design, methodology, product development, data analysis, and preparation of the original manuscript. **Weni Anggraini** contributed to the validation process, methodological review, data interpretation, supervision, and critical revision of the manuscript. **Setya Agustina** contributed to data collection, needs analysis, development of the practicum guidebook, administration of the limited-scale trial, data documentation, and preparation of the initial manuscript. All authors reviewed and approved the final version of the manuscript and agreed to be accountable for the accuracy and integrity of the work.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no financial, professional, institutional, or personal conflicts of interest that could have influenced the design, implementation, analysis, interpretation, or reporting of this study. The development and evaluation of the biology practicum guidebook were conducted solely for academic and educational purposes.

ETHICAL COMPLIANCE STATEMENT

This manuscript complies with research and publication ethics. The authors affirm that the work is original, conducted with academic integrity, and free from any unethical practices, including plagiarism.

STATEMENT ON THE USE OF AI OR DIGITAL TOOLS IN WRITING

During the preparation of this manuscript, the authors used a generative artificial intelligence tool solely to assist with English-language refinement, grammar correction, and improvements in academic readability. The tool was not used to generate research data, perform statistical analysis, determine the research findings, or formulate conclusions. All AI-assisted outputs were critically reviewed, revised, and verified by the authors. The authors take full responsibility for the accuracy, originality, interpretation, and integrity of the final manuscript.

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