

DEVELOPMENT OF A BIODIVERSITY E-BOOKLET THROUGH THE IDENTIFICATION OF HYDROCARBONOCLASTIC BACTERIA IN PETROLEUM WASTEWATER

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ABSTRACT

This study aims to determine the validity of the design of an E-Booklet on Hydrocarbonoclastic Bacteria in Petroleum Wastewater for biodiversity material for Grade X senior high school students. The research method used was descriptive qualitative with the ADDIE model consisting of five stages, namely Analyze, Design, Development, Implement, and Evaluate; however, the E-Booklet design in this study was carried out only up to the Development stage. The E-Booklet design stage was conducted at the Biology Study Program, Faculty of Teacher Training and Education, Bina Widya Campus, Universitas Riau. The designed E-Booklet was then validated by two validators, namely a media expert and a content expert. The validators' assessment of the E-Booklet was based on E-Booklet validity indicators consisting of three aspects: content, language, and format and graphics. The validity results of the E-Booklet design on Hydrocarbonoclastic Bacteria in Petroleum Wastewater obtained an average validity score of 3.84, indicating that the E-Booklet design falls into the very valid category and can be used as enrichment teaching material for biodiversity content for Grade X senior high school, Phase E.

Keywords: Hydrocarbonoclastic Bacteria; E-Booklet; Biodiversity.

INTRODUCTION

Biology learning at the senior high school level emphasizes the importance of students' understanding of biodiversity concepts, including the principles of classifying living organisms based on similarities and differences in characteristics. This material serves as a foundation for understanding more advanced concepts such as ecology, evolution, and relationships among organisms in ecosystems (Winanti, 2024). However, the learning process is often constrained by the lack of engaging, interactive, and contextual learning media. Learning media are an essential component of every learning process. The success of learning can be achieved through the creation of effective communication among the various elements involved in the learning process. One way to realize effective communication is by utilizing learning media. Learning media function as information delivery technologies that can be used in the teaching and learning process. With media supported by well-designed learning tools, students can be more guided in the learning process (Khairinal et al., 2021). In this regard, the selection of learning media is certainly an important aspect to consider. To ensure that learning objectives are achieved optimally, learning media must be varied.

Therefore, learning media that are able to attract students' attention and increase their learning motivation are needed. One form of teaching material that can serve as a medium to attract students' interest is an E-booklet. E-Booklet media are used to convey material in the form of concise summaries accompanied by attractive images, and researchers also insert character education into the media in electronic form that can be accessed via mobile phones and laptops (Hendrianti et al., 2021). The E-Booklet includes terminology and images from personal documentation as well as from various journal literature sources that can broaden students' knowledge, along with summarized explanations to make the material easier to understand. Thus, students can more easily comprehend the lesson material.

Based on the results of interviews conducted with a biology teacher at SMA Negeri 12 Pekanbaru, during the learning process on biodiversity material with the subtopic of classification of living organisms, the teacher used learning media in the form of textbooks, student worksheets (LKPD), and LKS. However, the biology teacher stated that the media used had not been fully successful in increasing students' motivation and interest in learning, because students still experienced difficulties in understanding biodiversity material with the subtopic of classification of living organisms. Therefore, innovation in learning media is necessary.

Electronic learning media emphasize the use of the latest technology in the development of instructional media (Septianto & Umam, 2017). Electronic-based media are characterized by concise, engaging, and easily understood material, complemented by many images, videos, and/or audio recordings (Fatimah & Mufti, 2014; Asyhari & Diani, 2017). Presenting booklets in digital form provides easier access and is able to increase student engagement in the learning process, especially for material that is often considered abstract, such as the classification of living organisms including the discussion of bacteria as part of the kingdom Monera. One local potential that can be utilized as a source for the development of teaching materials is the petroleum industry in Siak Regency.

Indonesia is a major oil-producing country and therefore has many activities related to petroleum extraction (Wardhani & Titah, 2021). Indonesia is one of the countries with the largest petroleum reserves in the world. According to SKK Migas (Special Task Force for Upstream Oil and Gas Business Activities), Indonesia's petroleum reserves in February 2024 were recorded at 4.7 billion barrels (Setiawan, 2024). Siak, as one of the petroleum-producing regencies in Riau Province, is known to play an important role in Indonesia's petroleum industry. This regency is known to have several petroleum storage tanks which, during the production process, generate a final product in the form of liquid waste that is discharged into waste disposal channels (Sayuti, 2015). The oil and gas industry is developing rapidly; however, its development may also potentially cause environmental pollution. Inadequate waste management can lead to pollution, so effective treatment methods are required. One commonly used technique is bioremediation, which is the process of degrading or detoxifying organic and inorganic pollutants using biological agents to restore environmental conditions (Melati, 2020). Microorganisms such as hydrocarbonoclastic bacteria play an important role because they are able to degrade hydrocarbon compounds by utilizing them as sources of carbon and energy (ESDM, 2010). Therefore, the isolation and identification of bacteria are necessary to determine the types of hydrocarbonoclastic bacteria present.

Studies on the identification and classification of hydrocarbonoclastic bacteria in petroleum wastewater are not only important for environmental management but also have the potential to become a contextual learning resource for the classification of living organisms at the senior high

school level. However, topics concerning bacteria in biodiversity discussions often receive limited attention. Therefore, the results of hydrocarbonoclastic bacteria identification from petroleum wastewater can be utilized to develop an informative e-booklet based on local potential. Based on this background, the development of an e-booklet based on the identification of hydrocarbonoclastic bacteria from petroleum wastewater from the petroleum industry in Siak Regency serves as an alternative learning medium that combines contextual and innovative learning and can be used in Grade X biology learning.

RESEARCH METHODS

This study employed a descriptive qualitative research design using the ADDIE model, which consists of five stages: Analyze, Design, Development, Implementation, and Evaluation. However, in this study, the E-Booklet design was carried out only up to the Development stage and was validated by media and content expert validators. The study was conducted at the Biology Education Study Program, Faculty of Teacher Training and Education, Universitas Riau, from June to August 2025. The E-Booklet was designed using the Canva application with a size of 21 × 14.8 cm (A5) and was then distributed via a Heyzine link.

E-Booklet Design

The E-Booklet design stage refers to the ADDIE model, which consists of five stages: analyze, design, development, implementation, and evaluation. However, in this study, the development was carried out only up to the development design stage by conducting validation with media experts and content experts. The E-Booklet design stage in this concept can be seen in the following flowchart.

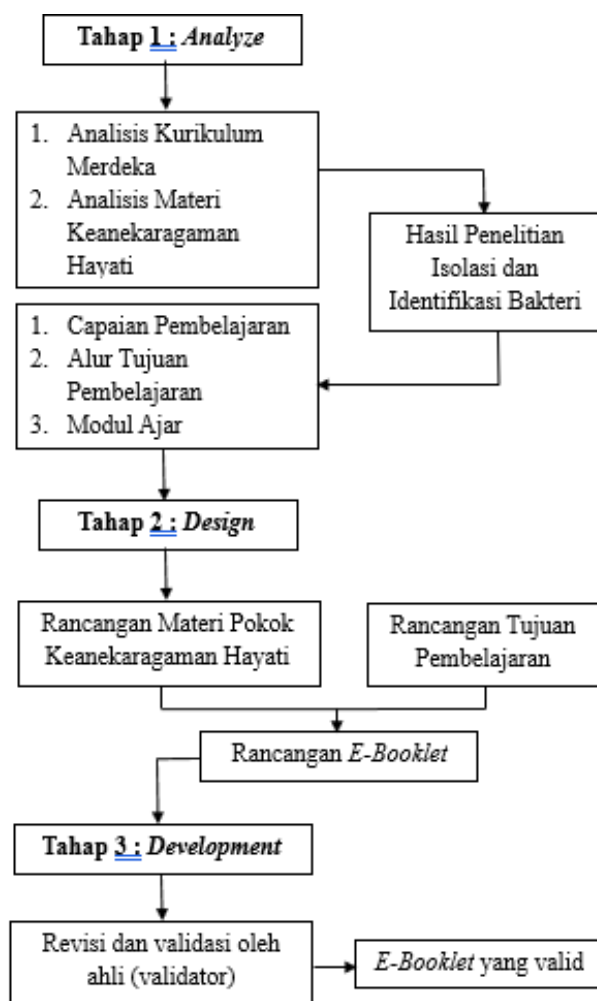


Figure 1. Flowchart of E-Booklet Development

Data Analysis Technique

After the E-Booklet design is completed, the E-Booklet validity test will be conducted by content expert validators and media expert validators. The researcher will provide validation sheets

to the content expert and media expert validators to assess the validity of the developed E-Booklet. There are four validity aspects to be assessed, namely material structure, language, and format and graphics. The validation instruments used consist of a content expert validation sheet and a media expert validation sheet. The aspects assessed in the E-Booklet validity can be seen in the following table.

Table 1. E-Booklet Validity Aspects

No	Aspect
1	Material Structure
2	Language
3	Format and Graphics

The analysis technique used is descriptive analysis, which is carried out by calculating the score of each indicator to determine the validity of the E-Booklet design. The validation process uses a Likert scale-based assessment with a score range of 1–4. The assessment categories can be seen in Table 2 below.

Table 2. E-Booklet Assessment Criteria

Assessment Score	Category
4	SS : Strongly Agree
3	S : Agree
2	KS : Somewhat Disagree
1	TS : Disagree

The validation results in the form of scores given by the validators are averaged using the following formula.

$$M = \frac{\sum Fx}{N}$$

Description :

M = Average score

ΣFx = Total score obtained

N = Number of validated components

The average score obtained is adjusted to the validity criteria table to determine the validity category of the E-Booklet. The criteria for decision-making on the validity of the E-Booklet design can be seen in Table 3 below.

Table 3. Validator Validity Criteria

Average Score Interval	Category
$3,25 \leq x \leq 4$	Very Valid
$2,5 \leq x \leq 3,25$	Valid
$1,75 \leq x \leq 2,5$	Less Valid
$1 \leq x \leq 1,75$	Not Valid

RESULTS AND DISCUSSION

E-Booklet Development

The research results obtained from the Identification of Hydrocarbonoclastic Bacteria in Petroleum Wastewater can be used as an E-Booklet for biodiversity material for Grade X senior high school students. The development of this E-Booklet used three stages, namely Analyze, Design, and Development.

Analyze (Analysis)

Based on the results of the curriculum analysis that has been conducted, studies related to the research results in the form of the Learning Objectives Flow for the Grade X biology subject can be seen in Table 4.

Table 4. Results of the Analysis of Learning Outcomes and Learning Objectives Related to the Research Results

Main Topic	Learning Outcomes	Learning Objectives	Learning Resources
Biodiversity	At the end of Phase E, students have the ability to understand measurement systems, alternative energy, ecosystems, biotechnology, biodiversity , atomic structure, chemical reactions, basic chemical laws, and climate change, so that they are responsive and able to actively participate in solving problems on local and global issues. All of these efforts are directed toward achieving the Sustainable Development Goals (SDGs).	<p>10.1.18 Students are able to identify one group of species in the 5-kingdom classification system such as bacteria</p> <p>10.1.19 Students are able to analyze the characteristics of species in the 5-kingdom classification system based on image observations</p> <p>10.1.20 Students are able to analyze the role of bacterial species in life</p>	E-Booklet

The results of the analysis of Learning Outcomes (CP) and Learning Objectives (TP) that are relevant to the research on the identification of hydrocarbonoclastic bacteria in petroleum wastewater can be utilized as enrichment teaching material through the development of an e-booklet on biodiversity material for Grade X. After the analysis of learning objectives and materials to be developed in the learning tools was obtained, the process was continued to the design stage (Design) of the e-booklet to be developed.

Design

At this stage, the learning tool design was prepared while simultaneously designing the e-booklet. The preparation of learning tools included the development of the learning objectives flow and teaching modules developed using the Problem-Based Learning (PBL) model. After that, the e-booklet design process was carried out using the Canva application. The details of the e-booklet design stages are presented in Table 5.

Table 5. E-Booklet Design

Page	Topic	Description
-	E-Booklet Cover	The E-Booklet cover consists of the e-booklet title, the name of the author, the supervising lecturer, illustrations of bacteria and the petroleum industry, the Universitas Riau logo, and the education logo.
I	Foreword	The foreword contains expressions of gratitude to Allah SWT and the author’s appreciation to all parties who assisted in completing the E-Booklet.
II	E-Booklet Guide	The e-booklet guide serves as a reference for understanding the content, presentation flow, and how to use the e-booklet effectively. In addition, this guide helps users utilize the features, structure, and information presented so that the learning process becomes more directed, easy, and efficient.
III	Table of Contents	It helps E-Booklet users understand the overall contents of the E-Booklet on Hydrocarbonoclastic Bacteria in Petroleum Wastewater.
IV	Learning Objectives and Learning Outcomes	It explains the knowledge, skills, and attitudes that students are expected to master.
1	Introduction	It contains general information about the research and the objectives of applying the research results to learning.

3-41	Material Description	It contains learning information about bacteria starting from the classification system of living organisms, the 5-kingdom classification system, the definition of bacteria, bacterial characteristics, bacterial cell structure, bacterial morphology, the role of bacteria, as well as information about hydrocarbonoclastic bacteria. It also includes tools, materials, and procedures used in the isolation and identification of hydrocarbonoclastic bacteria, as well as the types of bacteria that have been found.
42	References	It contains references used as sources in the preparation.
43	Backcover	It contains a brief profile of the author and a short summary of hydrocarbonoclastic bacteria.

Development

The final stage of this study was the development stage. The E-Booklet development stage was carried out by developing the framework/design of the E-Booklet that had been created previously.

Cover (Title, author’s name, supervisor’s name)

The E-Booklet cover consists of the E-Booklet title, the name of the researcher, and the supervising lecturer. The appearance of the E-Booklet cover was adjusted to the learning material. The E-Booklet cover design can be seen in the figure below.

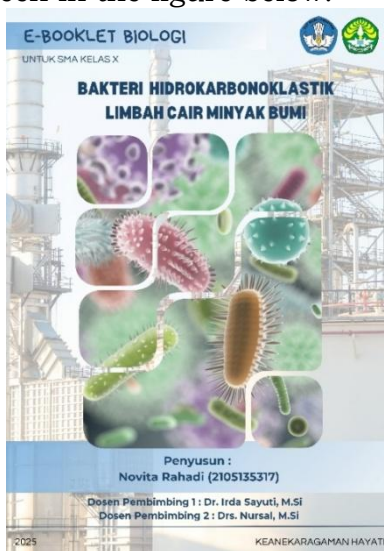


Figure 2. E-Booklet cover

Foreword

The foreword contains expressions of gratitude to Allah SWT and the author’s thanks to all parties who assisted in completing the E-Booklet. The design of the E-Booklet foreword can be seen in the figure below.

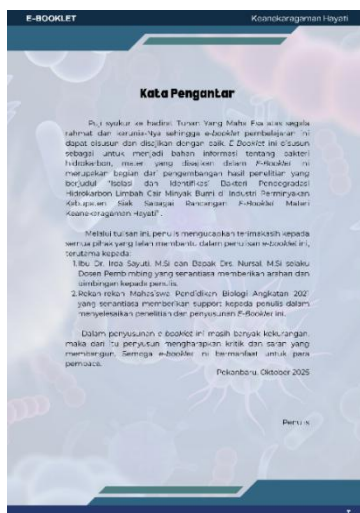


Figure 3. E-Booklet Foreword

E-Booklet Guide

The e-booklet guide serves as a reference for understanding the content, presentation flow, and how to use the e-booklet effectively. In addition, this guide helps users utilize the features, structure, and information presented so that the learning process becomes more directed, easy, and efficient. The E-Booklet guide can be seen in the figure below.

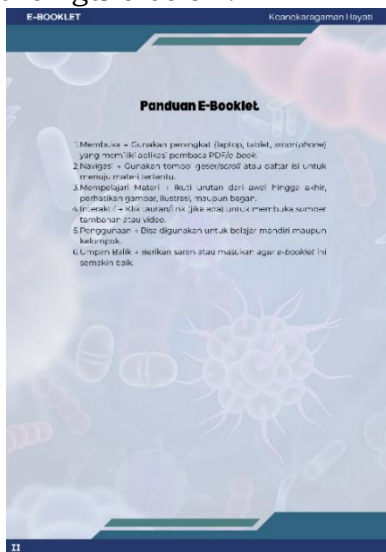


Figure 4. E-Booklet Guide

Table of Contents

The table of contents helps readers understand the contents of the E-Booklet on biodiversity. The design of the E-Booklet table of contents can be seen in the figure below.

The image shows a screenshot of the 'DAFTAR ISI' (Table of Contents) page. The page has a light blue background with a faint pattern of white circles. At the top, it says 'E-BOOKLET' and 'Keaneekaragaman Hayati'. The main title is 'DAFTAR ISI'. Below the title, there is a list of contents with page numbers: Kata Pengantar.....I, Panduan E-Booklet.....II, Daftar Isi.....III, Capaian Pembelajaran & Tujuan Pembelajaran.....IV, Pendahuluan.....1, Urutan Materi.....3, Sistem Identifikasi Mikroskopik Hidrokarbonoclastik Bakteri.....3, Definisi Bakteri.....5, Ciri dan Lamun USKOT.....5, Struktur dan Bentuk.....6, Morfologi sel bakteri.....9, Peranan Bakteri.....10, Isolasi Bakteri.....12, Identifikasi Bakteri.....14, Biologi Hidrokarbonoclastik.....20, Cara Kerja.....24, Isolasi Bakteri & Identifikasi Struktur.....29, Alat dan Bahan.....29, Jenis Bakteri.....36, Pustaka.....36, Enterooboclastop.....29, Daftar Pustaka.....45. At the bottom, it says 'UNTUK KELAS X SMA/IT/FASE E' and '2025'.

Figure 5. Learning Objectives and Learning Outcomes

Learning Objectives and Learning Outcomes

The researcher presents the learning objectives to make it easier for teachers, students, and readers to align them with the learning outcomes. The learning objectives can be seen in the figure below.

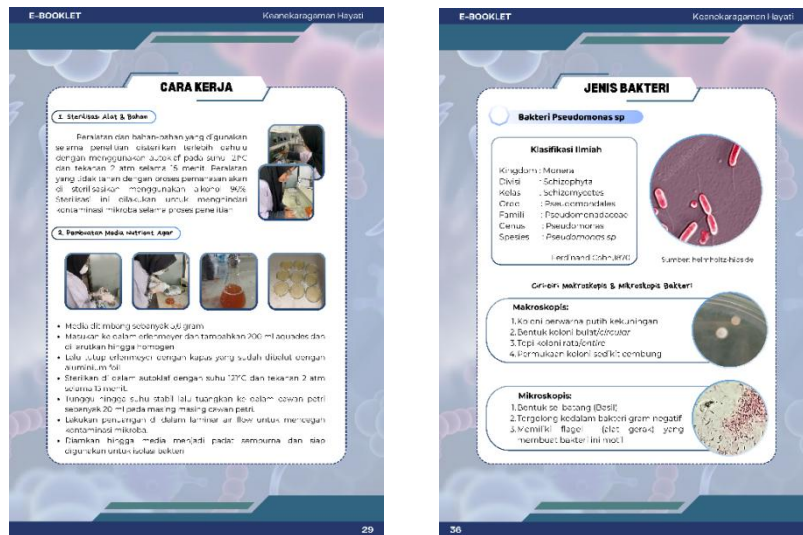


Figure 8. E-Booklet Material Description

References

The references section consists of citations of materials taken from various sources. This section is prepared in accordance with the principles of scientific writing and also serves to respect the original authors. The design of the E-Booklet references can be seen in the following figure.

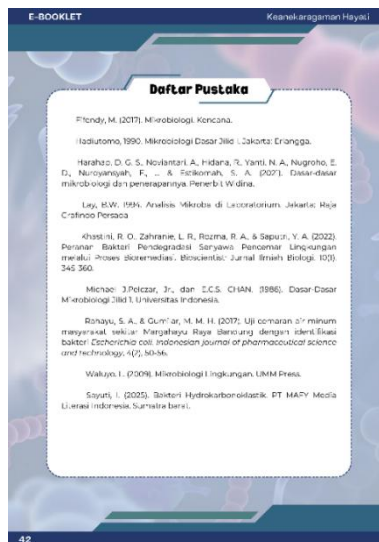


Figure 9. E-Booklet References

Backcover

This section contains a brief profile of the author and a short summary of hydrocarbonoclastic bacteria.



Figure 10. E-Booklet backcover

The developed E-Booklet was then validated by two validators, namely a media expert validator and a content expert validator. The validators' assessment of the pocket book was based on the validity indicators of the pocket book consisting of three aspects: material structure, language, and format and graphics.

Media Expert Validator

The results of the E-Booklet validation based on the assessment by the content expert validator can be seen in Table 6 below.

Table 6. Results of the Content Expert Validator Assessment on the E-Booklet

Aspect	Total Score	Average Score	Category
Material Structure	28	4	Very Valid
Language	19	3,8	Very Valid
Format and Graphics	44	4	Very Valid
Total		91	Very Valid
Average		3,96	

Based on Table 6, the average validation score given by the content expert on the aspects of the e-booklet was 3.96, which falls into the very valid category. This indicates that the developed E-Booklet on hydrocarbonoclastic bacteria in petroleum wastewater meets the feasibility criteria and can be used in learning.

Content Expert Validator

The results of the E-Booklet validation based on the assessment by the media expert validator can be seen in Table 7 below.

Table 7. Results of the Media Expert Validator Assessment on the E-Booklet

Aspect	Total Score	Average Score	Category
Material Structure	25	3,6	Very Valid
Language	19	3,8	Very Valid
Format and Graphics	42	3,8	Very Valid
Total		86	Very Valid
Average		3,73	

Based on Table 7, the average validation score given by the media expert on the aspects of the e-booklet was 3.73, which falls into the very valid category. This indicates that the developed E-Booklet on hydrocarbonoclastic bacteria in petroleum wastewater meets the feasibility criteria and can be used in learning.

Overall Average Validation

The overall average validation results of the e-booklet conducted by the content expert and the media expert can be seen in Table 8 below.

Table 8. Average Validation Results of the E-Booklet

Aspect	Validator		ΣScore	Average Score per Aspect	Category
	Media Expert	Content Expert			
Material Structure	25	28	53	3,80	Very Valid
Language	19	19	38	3,86	Very Valid
Format and Graphics	42	44	86	3,90	Very Valid
Total	86	91	178	11,56	Very Valid
Average	3,73	3,96	3,84	3,84	

Based on Table 8, the validation results from both validators show an average score of 3.84 in the very valid category. This indicates that the developed e-booklet on hydrocarbonoclastic bacteria in petroleum wastewater is considered feasible and can be utilized as enrichment material in biology learning. These results also indicate that the content, language, presentation, and graphics of the e-booklet meet the assessment criteria, thereby supporting the learning process and improving students' understanding of hydrocarbonoclastic bacteria.

CONCLUSIONS

The validity results of the hydrocarbonoclastic bacteria in petroleum wastewater e-booklet design obtained an average validity score of 3.84; therefore, this e-booklet design falls into the very valid category and can be used as enrichment teaching material for biodiversity content for Grade X senior high school, Phase E.

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