

The Development of a Conceptual Change-Oriented E-Book in Environmental Science

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Abstract: Environmental science e-books that focus on conceptual change are educational resources that offer firsthand knowledge and complement environmental science lectures. This study aims to describe the design of the e-book, the responses of the validators, and the students' responses after the e-book was used as teaching material. The type of research conducted was Research and Development (R&D) with modifications to the Dick and Carey model, which includes three stages, namely the planning stage, the development stage, and the implementation stage. The development procedures included problem identification, data collection, e-book design, design validation, e-book revision, and product testing. The concept change-oriented environmental science e-book was designed per the format of a textbook consisting of four components: the book's exterior, the front part of the textbook, the content part, and the back part. This e-book is valid, practical, and effective, making it suitable as an independent learning resource for students. The linguistic validation results show that this e-book is valid with a score of 0.75. In a small group trial, this e-book was rated practical and effective with a percentage of 95.05%. In a large group trial, this e-book was also rated practical and effective with a percentage of 95.89%.

Keywords: Conceptual Change-Oriented; E-books; Environmental Science.

Introduction

The development of science and technology inevitably influences education because it encourages the need for renewal by utilizing technology, which can serve as an interactive medium between teachers and students (Hanifah Salsabila et al., 2020). One of the technologies used in learning is to facilitate students and teachers in achieving learning objectives. In attaining learning objectives, appropriate learning resources are needed. The use of technology is crucial for staying current. Information and communication technology development is increasingly urgent, especially in education (Ahillon Jr & Aquino, 2023; Arciosa, 2022; Rohmah & Rachmawati, 2019; Shah,

2022). In line with current technological developments, electronic resources known as e-books have emerged. One aspect of learning considered suitable and relevant for independent study is teaching materials. Teaching materials are packaged comprehensively and sequentially, and their content includes a set of planned learning experiences designed to help students master more specific learning objectives. The ability of teachers to create teaching materials plays a crucial role in determining the success of the learning process through the development of effective teaching materials (Annisa & Nofrita, 2023). The higher the teachers' emotional intelligence, the better their performance will be (Zebua & Siahaan, 2021).

E-books are digital versions of printed books developed with special applications, which are more

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practical, easier to duplicate, and more durable than printed books. Interactive e-books as a learning medium can support students' science skills and can be one of the teaching materials that can be used to support the learning process (Harvareza et al., 2023). E-books provide students with easier, faster, and more affordable access to learning materials. Students can freely read and understand the material in various places and at any time through their electronic devices. In addition, e-books allow educators to update and adapt learning content in line with developments in knowledge and student needs and create a more inclusive, innovative, and sustainable learning environment for all students (Ningsih & Ulya, 2024). The importance of this research lies in its contribution to the world of education in presenting a more comprehensive and contextual approach to learning (Samaniego et al., 2024; Villegas-Ch & García-Ortiz, 2023; Wasim et al., 2024). By utilizing digital technology, the developed e-book provides a more engaging learning experience that stimulates students' curiosity about the subject matter, aligning with current student needs and facilitating independent learning. In addition, the integration of Pancasila values in these e-books supports the national education goal of shaping a generation that is not only superior in cognitive aspects but also has a strong character and is oriented towards national values (Ardiansyah et al., 2024; Holmes, 2019; Jain, 2024; Khasawneh & Khasawneh, 2023; Ramadhan & Arisetyanto Nugroho, 2024; Sumantri, 2022; Tiara et al., 2023).

One of the courses in the Biology Education study program that can be taught using e-books is environmental science. Environmental science is a branch of ecology that applies various principles and concepts to broader environmental issues, examining the interrelations between humans and their environment. The Biology Education Study Program at PGRI Silampari University (UNPARI) has a compulsory Environmental Science course. Environmental problems such as global warming threaten the survival of humans and animals and reduce the quality of the environment. Global warming and climate change are currently major international issues and threats to the sustainability of life in the future (Amin et al., 2020). Furthermore, research by Chozo (2024) reveals emerging thematic focuses, such as sustainability, climate change adaptation, and biodiversity conservation, which reflect the field's response to pressing global environmental challenges.

Students have been receiving material sourced from lecturers and several articles they find on the internet, which are too broad in scope, so that students often encounter obstacles in learning a concept (Sukmawati et al., 2020). The application of conceptual change-based learning is an effort to reduce

misconceptions by confronting them through cognitive conflict (Pebriyanti et al., 2015).

Based on observations and interviews with students taking environmental science courses in the Biology Education Program in the first semester at PGRI Silampari University (UNPARI), it is known that many still experience difficulties in learning environmental science concepts and have misconceptions. The lack of updated teaching materials/environmental science books currently requires lecturers to produce the latest teaching materials in accordance with the current needs of students. This is expected to encourage students to become actively involved, creating an interesting and enjoyable atmosphere and maximising learning outcomes. Therefore, one way to overcome students' difficulties in understanding environmental science concepts is to provide high-quality and practical e-books. Environmental science e-books that focus on conceptual change are educational resources that offer firsthand knowledge and complement environmental science lectures.

This research is based on the unavailability of *the* latest environmental science *e-books* oriented towards *conceptual change*, which are believed to have more value than just reference reading, but also can identify environmental problems and instill values of environmental love in conservation efforts, so that lectures run effectively and efficiently. Based on these considerations, it is necessary to compile and develop teaching materials to produce *an e-book* on environmental science oriented *towards conceptual change* at PGRI Silampari University (UNPARI). This study aims to describe the design of the *e-book* and the responses of validators and students after using the *e-book*, resulting from the development of teaching materials.

Method

This type of research is Research and Development (R&D) research, involving the development of modified teaching materials from the Dick and Carey model, which includes three stages. The first stage is the planning stage (conducting observations and compiling a plan for e-book development activities), the second stage is the development stage (covering analysis and estimation of the needs to develop the basic framework of e-book material, identifying learning objectives and learning outcomes, designing the e-book framework, creating the e-book, and revising the e-book), and the third stage is the implementation of the e-book. This process involves developing e-books for product creation, validating educational materials, and gathering student feedback on using environmental science e-books

designed to promote conceptual change. The goal is to assess the validity, practicality, and effectiveness of these e-books. The steps in this research included needs and objective analysis, design, development, evaluation, a student response questionnaire, and Revision of the conceptual change-oriented environmental science e-book, followed by feedback. R&D research differs from qualitative and mixed research approaches. A significant increase in the

Number of research publications in science education has been observed, especially since 2017 (Muchson et al., 2024).

The development procedure includes identifying potential problems, collecting data, designing the e-book, validating the design, revising the e-book, and testing the product (one-to-one, small, and large group testing).

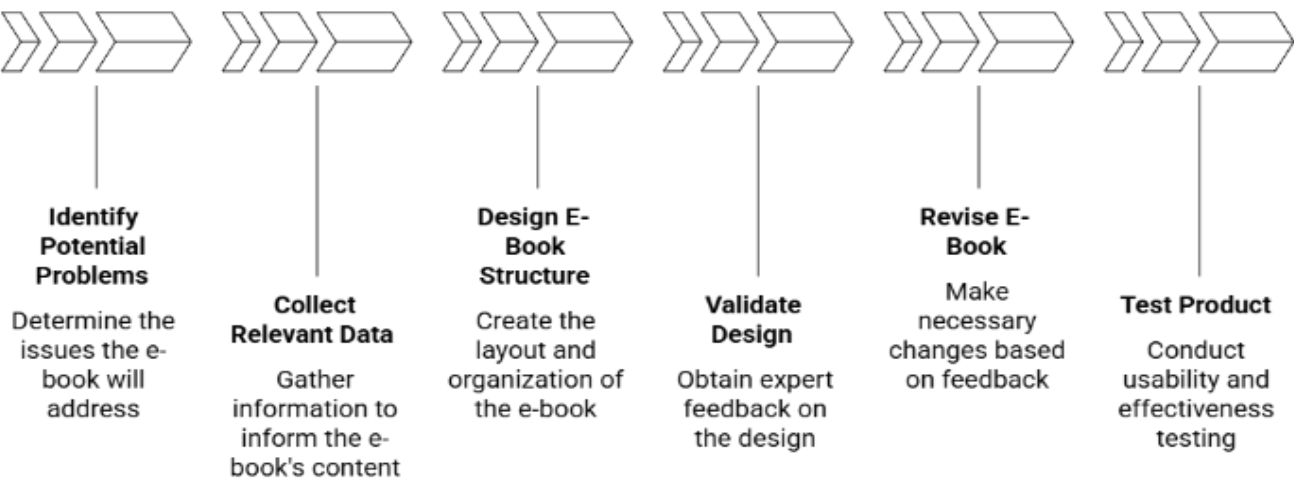


Figure 1. E-book Development Procedure

The data collection technique used in this study was a closed questionnaire containing questions given to validators and students to determine the effectiveness of the conceptual change-oriented environmental science e-book created by the researcher. The questionnaire was given to students to assess the extent to which the conceptual change-oriented environmental science e-book was accepted.

Data analysis techniques were used to analyse the data obtained through validation questionnaires from validators and student response questionnaires. Valid and reliable measurement tools ensure that the data collected accurately reflects the studied variables, which is crucial for drawing valid conclusions (Souza et al., 2017).

Data analysis was used to group information from qualitative data, including responses and suggestions for improvement. The data analysis was a reference for improving or revising the product (Sofiyana et al., 2016). Validity data were obtained to measure the validity of the developed concept-change-oriented environmental science e-book. The validity data analysis used a score of 1-5, with each Score having a different description.

Table 1. Expert Validation Assessment Score Guidelines

Item responses	Score (Negative statement)	Instrument item response	Score (Positive statement)
Very inappropriate	1	Very appropriate	5
Somewhat appropriate	2	Good	4
Fair	3	Fair	3
Good	4	Less suitable	2
Very suitable	5	Very unsuitable	1

The formula used in the data validation analysis uses Aiken's V validation:

$$V = \frac{\sum s}{n(c-1)} \tag{1}$$

Explanation:
V = Respondent agreement index regarding item validity
s = Score assigned by respondents minus the lowest Score (s = r-1)
r = the category score chosen by the Respondent
n = Number of respondents
c = Number of choice categories filled in by respondents

Table 2. Content Validity Criteria

Average Score	Validity Level
$0.8 < V \leq 1.0$	Highly Valid
$0.4 < V \leq 0.8$	Fairly Valid
$0 < V \leq 0.4$	Less Valid

In this study, feasibility is agreed upon with a minimum score categorized as sufficient. Suppose the results provided by the validator and students obtain an average score of enough. Developing an environmental science e-book oriented towards conceptual change is feasible.

This section analyzes and measures the Percentage of student responses to the tested product. The guidelines for scoring student responses are as follows:

Table 3. Student Response Assessment Score Guidelines

Instrument Item Answers	Score (Negative Statement)	Instrument item response	Score (Positive statement)
Strongly Agree	1	Strongly Agree	4
Agree	2	Agree	3
Disagree	3	Disagree	2
Strongly disagree	4	Agree	1

The total assessment score in data analysis can be calculated using Formula 2:

$$P = \frac{f}{N} \times 100\% \quad (2)$$

Explanation:

P = Percentage of survey data

f = Total Score obtained

N = Maximum Number of scores

In converting the product validity score, the following guidelines are used:

Table 4. Quantitative-Qualitative Data Scores

Value	Percentage	Qualitative Data
A	84-100	Very practical
B	68	Practical
C	52-68	Fairly Practical
D	36-52	Not Practical
E	0-36	Very impractical

In this study, feasibility was agreed upon with a minimum sufficient score. If the results provided by students obtained a sufficient average score, then the development of an environmental science e-book oriented towards conceptual change was considered practical for use.

Results and Discussion

The research results on developing an environmental science e-book oriented towards conceptual change went through four stages. The first stage involved analyzing needs and objectives, the second stage focused on designing, the third stage entailed developing teaching materials, and the fourth stage involved evaluating and revising. These stages aimed to produce an environmental science e-book oriented towards conceptual change that was valid, practical, and effective.

Analysis of Needs and Objectives

The analysis of needs and objectives aimed to identify the gap between the current and desired situations, and to determine the changes in students before and after using the teaching materials developed by the researcher. Based on the results of observations during three meetings, it was found that there was no e-book on environmental science oriented towards conceptual change, limited reference sources on ecological science, the books used by students were monotonous, not varied, and had not been updated with current developments, there were no structured assignments in the books used, and the reference sources had not been updated.

Meanwhile, the needs of students from the questionnaire results also showed that learning e-books on environmental science oriented towards conceptual change are a guide that accommodates ecological science issues and efforts/solutions from real-life problems, as well as teaching media that are packaged attractively and accommodate various forms, such as images, animations, audio, and video. Based on the results of identifying problems and learning needs for e-books on environmental science oriented towards conceptual change, researchers attempted to design e-books on environmental science oriented towards conceptual change that can make students think more scientifically while training their critical thinking skills.

Design

After conducting a needs and objectives analysis, the next step is identifying the learning outcomes. Learning outcomes are identified to determine the content of the environmental science e-book oriented towards conceptual change based on skills, processes, procedures, and learning tasks adapted to the Semester Learning Plan (RPS).

The learning analysis (students) and context conducted by researchers in the field was to identify and analyze the characteristics and abilities of students during lectures. Students desired an environmental science e-book oriented towards conceptual change that contained comprehensive and easy-to-understand

material. The researcher formulated performance objectives, namely instructional objectives, learning outcomes, and final competencies to be achieved by students after using the conceptual change-oriented environmental science e-book.

The instruments developed by the researcher were in the form of essay questions that would measure students' understanding of the concepts of the developed materials, while also training students to answer questions scientifically and critically. The essay questions were developed based on the learning objectives in each chapter of the conceptual change-oriented environmental science e-book.

Based on the information obtained in the field, the researcher designed lectures in the RPS, which were then developed in the conceptual change-oriented environmental science e-book.

Development

At this stage, the researcher developed teaching materials according to the anatomy of textbook writing. The conceptual change-oriented environmental science e-book was designed in accordance with the form of textbook writing, which contains four components consisting of the outer parts of the book (front cover, spine cover, back cover), the front part of the textbook (title page, foreword, and table of contents), the body of the textbook (chapter titles, introduction, content, and assignments), and the back matter (containing the bibliography and author's biography/history). The e-book on environmental science, oriented towards conceptual change, provides students with a theoretical understanding of essential concepts. This aims to prevent misconceptions in recognising and understanding various materials through a scientific approach, focusing on environmental issues and solutions to overcome environmental problems. This information can come from anywhere, anytime, and does not depend on one-way information from lecturers.

Evaluation and Revision

The next stage in developing teaching materials for listening skills is the evaluation and revision stage. The stages are: a) expert evaluation; b) individual evaluation; and c) field testing. Expert evaluation is conducted to determine the validity of the teaching materials developed. The analysis of this validity data is assessed based on language experts, media experts, and material feasibility experts using Formula 3:

$$V = \frac{\sum S}{[n(c-1)]} \quad (3)$$

Explanation:

S = r - lo

Lo = Lowest validity score

c = Highest validity score

r = Score given by the assessor

Table 5. Range of Teaching Material Validity Criteria

Correlation Coefficient	Validity Interpretation
> 0.80	Highly valid
$0.60 \leq V < 0.80$	Valid
$0.40 \leq V < 0.60$	Fairly valid
$0 \leq V < 0.40$	Not valid

Language Expert

The expert assessment of linguistic aspects covers the overall use of language in the conceptual change-oriented environmental science e-book developed by the researcher. This expert assessment of linguistic aspects consists of four statements regarding easy-to-understand language, clarity of information, compliance with EYD Indonesian language rules, and effective and efficient use of language. Based on the results of the linguistic expert assessment of the conceptual change-oriented environmental science e-book.

The results of the above calculations show that the language validity data from several components of the research instrument statements obtained an average V score of 0.75, which is categorised as **valid** according to the interpretation of Aiken's V validity in the correlation coefficient $0.60 \leq V < 0.80$.

Suggestions and comments from linguists regarding this teaching material are as follows: 1) The wording of the introduction has been revised as suggested, 2) There are several typos in the table of contents, 3) Each image should have a number and explanation, examples of which can be found in the teaching material book, including the sources. For example, the font size is smaller for internet or personal documents. 4) On several pages, there are instances of incorrect use of lowercase and uppercase letters, which should be varied according to the instructions in the teaching materials. 5) Use lowercase letters if a conjunction is in the middle of a subheading.

Media Expert

The textbooks that have been developed are also evaluated by media experts. The evaluation of the appearance of printed textbooks aims to determine the suitability and appropriateness of the textbook's appearance. The assessment of the appearance of the textbook covers the clarity of objectives, the order of presentation, motivation, interaction (stimulus and response), completeness of information, font size and type, accuracy of illustrations/graphics/tables, cover, and physical appearance. Based on the assessment results of the presentation and graphics in the environmental science e-book, which is oriented towards conceptual change.

The results of the above calculations show data on the validity of the design of several components of the research instrument statements, which obtained an average V score of 0.92 in the highly valid category, which is in line with Aiken's V validity interpretation in the correlation coefficient > 0.80 . The suggestions and comments from presentation and graphic design experts regarding this teaching material are that the environmental science e-book can be used without Revision.

Material Feasibility Expert

The assessment of the environmental science e-book's content, oriented towards conceptual change, aims to evaluate its suitability for students as a reference book in the Environmental Science Course. The assessment of content comprises several indicators, including suitability with the curriculum/competency standards/syllabus; suitability of teaching materials for student development; suitability of teaching materials with teaching material requirements; accuracy of material substance; suitability of material with exercises; suitability of material with evaluation; and benefits for increasing knowledge. Based on the results of the material feasibility expert's assessment of the conceptual change-oriented environmental science e-book.

Calculating material validity data from several components of the research instrument statements obtained an average V value of 0.68 with a **valid** category per the interpretation of Aiken's V validity in the correlation coefficient of $0.60 \leq V < 0.80$. There were no suggestions or comments from material experts regarding this teaching material. Conclusions regarding the results of the calculations for the three validations of the overall assessment of the conceptual change-oriented environmental science e-book can be seen in Table 6.

Table 6. Validator Assessment

Validator	Score Obtained		
	Language	Graphics	Content
Validator 1	0.75	-	-
Validator 2	-	0.92	-
Validator 3	-	-	0.68

Based on the table above, the language validation assessment obtained an average V of 0.75 with **valid** criteria. Meanwhile, media validation obtained an average V of 0.91, indicating it is highly valid, and material validation obtained an average V of 0.68, indicating it is **valid**. Therefore, the environmental science e-book oriented towards conceptual change is **suitable for use** and can be tested at the practical stage (individual testing and field testing).

Prototype Evaluation

The one-to-one evaluation was conducted on November 3, 2022. The steps taken were: 1) The researcher distributed the Listening Skills teaching materials to students; 2) Students browsed and read the conceptual change-oriented environmental science e-book; 3) The researcher conducted a question-and-answer session related to the content of the teaching materials. This one-to-one evaluation was done using a questionnaire (survey) on three students.

Based on the questionnaire scores obtained from six students, a total of 192 points was obtained. Then, the result was calculated using a formula to be 100%. This demonstrates that the environmental science e-book, oriented towards conceptual change, is practical and effective. Furthermore, the teaching materials will be tested on a broader scale. Based on the results of this one-to-one implementation, it is known that the environmental science e-book oriented towards conceptual change is exciting and valuable. According to the students, the language used is easy to understand. The text includes examples of environmental problems and solutions, as well as unique pictures. Students also easily understood the content of the conceptual change-oriented environmental science e-book. The language used was simple, making it easy for students to answer the questions and practice their critical thinking skills. Based on this, it can be concluded that the conceptual change-oriented environmental science e-book developed by the researcher can be used by students and lecturers when conducting lectures.

Implementation of Small Group Evaluation

The small group evaluation was carried out by distributing a questionnaire provided by the researcher to six students. The steps taken in the small group evaluation stage were: 1) Students read and understood the material in the conceptual change-oriented environmental science e-book; 2) Next, the researcher distributed questionnaires to the six students regarding the conceptual change-oriented environmental science e-book; 3) After that, students were asked to answer sixteen questions in the questionnaire. Based on the questionnaire scores obtained from the six students, a total questionnaire score of 365 was obtained. Then, using a formula, the result of 95.05% was obtained. This demonstrates that the conceptual change-oriented environmental science e-book is practical and effective. Next, the teaching materials will be tested on a broader scope. The components of the teaching materials that need to be improved are: 1) The wording of the introduction has been corrected as suggested; 2) The table of contents contains several typos; 3) Each image should have a number and explanation, examples of which can be found in the teaching materials book,

including the sources. For example, from the internet or personal documents, the font size is smaller; 4) On several pages, there are instances of incorrect use of lowercase and uppercase letters, which should be varied according to the instructions in the teaching materials; 5) Connecting words in the middle of subheadings should use lowercase letters.

After the corrections were made, the revised version was obtained, where the preface had been revised according to the suggestions. After Revision, the foreword was aligned with the language expert's tips.



Figure 2. Appearance of the Foreword (a. Before Revision and b. After Revision)

There were several typos in the table of contents. After Revision, the table of contents has no typos.

DAFTAR ISI		DAFTAR ISI	
HALAMAN SAMBUL	I	HALAMAN SAMBUL	I
KATA PENGANTAR	II	KATA PENGANTAR	II
DAFTAR ISI	III	DAFTAR ISI	III
I. PENDAHULUAN		I. PENDAHULUAN	
A. PENGERTIAN DASAR DASAR ILMU LINGKUNGAN	2	A. PENGERTIAN DASAR DASAR ILMU LINGKUNGAN	2
B. Cabang/Aspek Ekologi	3	B. Cabang/Aspek Ekologi	3
C. Penerapan Aplikasi Ekologi	5	C. Penerapan Aplikasi Ekologi	5
D. Tren Lingkungan	6	D. Tren Lingkungan	6
E. Istilah-istilah Ekologi	8	E. Istilah-istilah Ekologi	8
F. Macam-Macam Ekologi	11	F. Macam-Macam Ekologi	11
II. MANUSIA DAN LINGKUNGAN		II. MANUSIA DAN LINGKUNGAN	
A. Pengertian/Definisi Hubungan Manusia dan Lingkungan	13	A. Pengertian/Definisi Hubungan Manusia dan Lingkungan	13
B. Elita Lingkungan	15	B. Elita Lingkungan	15
C. Pandangan Manusia Terhadap Lingkungan	20	C. Pandangan Manusia Terhadap Lingkungan	20
III. PRINSIP-PRINSIP LINGKUNGAN		III. PRINSIP-PRINSIP LINGKUNGAN	
A. Prinsip-prinsip Lingkungan	24	A. Prinsip-prinsip Lingkungan	24
B. Masalah-masalah Lingkungan yang Utama	26	B. Masalah-masalah Lingkungan yang Utama	26
V. MASALAH MASALAH LINGKUNGAN		V. MASALAH MASALAH LINGKUNGAN	
A. Solusi dan Dasar Manusia	29	A. Solusi dan Dasar Manusia	29
B. Lalu Belakng Timbulnya masalah Lingkungan	31	B. Lalu Belakng Timbulnya masalah Lingkungan	31
C. Rangk Lingkup Masalah Lingkungan	36	C. Rangk Lingkup Masalah Lingkungan	36
VI. KONSEP SUMBERDAYA ALAM		VI. KONSEP SUMBERDAYA ALAM	
A. Definisi Sumberdaya Alam	37	A. Definisi Sumberdaya Alam	37
B. Klasifikasi Sumberdaya Alam	38	B. Klasifikasi Sumberdaya Alam	38
C. Siklus Sumberdaya Alam	39	C. Siklus Sumberdaya Alam	39
D. Dilema dan Keterbatasan Sumberdaya Alam	40	D. Dilema dan Keterbatasan Sumberdaya Alam	40
VII. MASALAH MASALAH YANG TERPAKAI DENGAN SUMBERDAYA ALAM		VII. MASALAH MASALAH YANG TERPAKAI DENGAN SUMBERDAYA ALAM	
A. Definisi Sumberdaya Alam	44	A. Definisi Sumberdaya Alam	44
B. Klasifikasi Sumberdaya Alam	45	B. Klasifikasi Sumberdaya Alam	45
C. Persepsi Keterbatasan Sumberdaya Alam	53	C. Persepsi Keterbatasan Sumberdaya Alam	53
VIII. KONSEP SUMBERDAYA ALAM		VIII. KONSEP SUMBERDAYA ALAM	
A. Definisi Konsep Sumberdaya Alam	57	A. Definisi Konsep Sumberdaya Alam	57
B. Pembagian/Definisi/Aspek/Topik/Integrasi Lingkungan SDG	59	B. Pembagian/Definisi/Aspek/Topik/Integrasi Lingkungan SDG	59
C. Konsep Sumberdaya Alam	60	C. Konsep Sumberdaya Alam	60
D. Konsep Sumberdaya Alam	61	D. Konsep Sumberdaya Alam	61
E. Konsep Sumberdaya Alam	69	E. Konsep Sumberdaya Alam	69
IX. PEMANUSIA LINGKUNGAN		IX. PEMANUSIA LINGKUNGAN	
A. Pengertian Pemanusia	103	A. Pengertian Pemanusia	103
B. Aspek Pemanusia	104	B. Aspek Pemanusia	104
C. Pemanusia dan Perilaku	110	C. Pemanusia dan Perilaku	110
D. Sumber Pemanusia	115	D. Sumber Pemanusia	115
X. PENGARUH BERBAGAI MACAM PEMANUSIA LINGKUNGAN		X. PENGARUH BERBAGAI MACAM PEMANUSIA LINGKUNGAN	

Field Test Implementation

The field test was conducted on 18 students who filled out a questionnaire consisting of 16 questions. Based on the questionnaire scores obtained from 18 students, a total questionnaire score of 982 was obtained. Then, using a formula, the result was calculated to be 95.89%. This shows that it is convenient to use. The large test group of students commented that the e-book was exciting, excellent, very useful, and clear/easy to understand, making it very helpful in learning.

This study aims to develop a conceptual change-oriented environmental science e-book based on a scientific approach and to determine the validity, practicality, and effectiveness of the conceptual change-oriented environmental science e-book. The stages carried out in this study were: potential and problems, data collection, e-book design, expert validation, product revision, product testing, and product revision. Based on the results of the needs analysis questionnaire in the field, it is known that there is no environmental science e-book oriented towards conceptual change, limited environmental science book references, the books used by students are monotonous, not varied, and have not been updated with current developments, there are no structured assignments in the books used, and the references have not been updated.

The needs of students from the questionnaire results also show that learning e-books on environmental science oriented towards conceptual change are a guide that accommodates ecological science issues and efforts/solutions to real-life problems, as well as teaching media that are packaged attractively and accommodate various forms, such as images, animations, audio, and video. Based on the results of identifying problems and learning needs for conceptual change-oriented environmental science e-books, researchers attempted to design conceptual change-oriented environmental science e-books that could make students think more scientifically while training their critical thinking skills.

After the teaching materials were developed, the next step was the validation stage by three experts: language and subject matter experts. The results of the linguistic validation showed that the design of the conceptual change-oriented environmental science e-book was valid for use with a score of 0.75. Using reasonable and appropriate language in the e-book makes it easy for students to understand the studied material (Sholihah, 2025).

Then, the media validation results obtained a score of 0.92 with a category of highly valid. Using attractive images can improve learning outcomes in students (Hasan et al., 2021). Good learning material is presented with the help of good visuals, one of which is images. Meanwhile, the expert assessment of the

material obtained a score of 0.68, which is in the valid category (Daryanto, 2016; Kustandi et al., 2021). The scope and material must align with the correct concepts and theories (Dewi & Rachmadiarti, 2018). According to (Cahyani et al., 2020), the design of attractive media can motivate students to learn, thereby achieving the predetermined learning objectives. In line with the opinion of Dianis et al. (2024), if an E-Book is equipped with images, videos, and other electronic features, it can increase students' active thinking patterns. E-books are considered very valid from a linguistic perspective. This indicates that e-books already adhere to Indonesian language rules, which are easy to understand. According to Hermawan (2019), students' interest in reading and understanding the available material is influenced, among other things, by language and sentences that are good and easy for students to understand.

Based on the opinions of the three experts, it can be concluded that the design of the environmental science e-book oriented towards conceptual change is suitable for use, despite some notes from the validators. During the media validation, suggestions and comments were provided, namely that the editorial of the introduction had been corrected as suggested; there were several typos in the table of contents; each image should have a number and explanation, and examples can be found in the teaching materials, including the sources. For instance, from the internet or personal documents, the font size is smaller; on several pages, there are instances of incorrect use of lowercase and uppercase letters, which should be varied according to the instructions in the teaching materials; for connectors in the middle of subheadings, use lowercase letters. The researcher has corrected all criticisms and suggestions from the validators for further field testing.

Through one-to-one evaluations with three students, the questionnaire results showed that the conceptual change-oriented environmental science e-book was practical and effective, with a percentage of 95.05%, making it suitable for use. Three students stated that the conceptual change-oriented environmental science e-book was exciting and helpful, with attractive and unique images that prevented students from getting bored while reading it. Furthermore, regarding the content of the conceptual change-oriented environmental science e-book, students stated that it was easy to understand because it used simple language, making it easier for students to understand the material and answer questions correctly while improving their critical thinking skills. Furthermore, in a small group trial of six students who filled out a questionnaire consisting of 16 questions about the appearance of the conceptual change-oriented environmental science e-book, the content of the conceptual change-oriented environmental science

e-book, the images and illustrations used, and the language used in the conceptual change-oriented environmental science e-book. The questionnaire results showed that the conceptual change-oriented environmental science e-book was practical and effective, with a percentage of 95.05%. The e-book provided was exciting and greatly added to the students' knowledge, coupled with the inclusion of examples from images that were very relevant to everyday life, and could be carried anywhere, making it easy to learn.

Then, the conceptual change-oriented environmental science e-book was tested on a large group of students, who filled out a sixteen-question questionnaire on practicality and effectiveness. The questionnaire results showed that the conceptual change-oriented environmental science e-book is practical and effective, with a percentage of 95.89%. The students in the large test group commented that the e-book was exciting, good/excellent, helpful, and clear/easy to understand, thus greatly assisting in the learning process. An e-book is an electronic book that can be accessed effectively and efficiently (Almunawaroh, 2020). The e-book on environmental science, which is oriented towards conceptual change, is designed to strengthen learning by presenting material that is not only a reference but also provides solutions to environmental problems and stimulates students' interest in independent and effective learning (Hendri et al., 2025).

E-books can facilitate interactive access to learning resources with multimedia features that can increase the appeal and effectiveness of science learning, supporting a deeper understanding of Archimedes' principles. Immersive Virtual Reality (IVR) has the potential to be a good educational strategy for sustainability, in line with its ability to visualize information and interact with more engaging content, facilitating increased environmental awareness and literacy among the community (Al Mohsen & Alqassab, 2023; Fairuz et al., 2025; Fajar et al., 2025; Febrianti et al., 2022; Khudri et al., 2025; Nunes et al., 2025). The use of e-books in science learning can improve students' conceptual understanding of aspects of science as products, process skills, attitudes, and technologies that are closely related to the surrounding environment (Chercules et al., 2023; Kamila et al., 2025; Lase & Lase, 2020) – developing a Google Sites-based E-LKPD with a PBL model oriented towards conceptual change to improve students' scientific literacy in environmental science material interactively and effectively through the e-book format. Concept-oriented environmental science has received a very positive response from observers. It is considered suitable as an independent learning resource that can improve students' understanding of ecological concepts through an

interactive and contextual learning approach (Lestari et al., 2025). The development of this Google Sites-based e-book focuses on students' conceptual change in environmental science learning, to increase its validity and practicality as an adaptive digital learning medium at the high school level (Jannah et al., 2024). The development of flipbook-style digital learning media oriented towards concept change can improve science learning outcomes with a project-based learning approach, which is relevant for strengthening Environmental Science material through interactive e-book media (Nursafitri & Ansori, 2024). E-books are essential in realising more environmentally friendly and efficient education, which is a solution to reduce paper use and increase efficiency and accessibility in education (Ningsih & Ulya, 2024). The use of e-books as a learning medium for environmental science to improve students' science process skills (Marjanah et al., 2025; Putri et al., 2024). Conceptual changes in ecological science material aimed at enhancing students' critical thinking skills and learning outcomes through innovative and adaptive interactive learning media (Mahanani & Suhartini, 2025).

Next, a product trial was conducted over four meetings, and tasks in the environmental science e-book were completed, oriented towards conceptual change. Learning was carried out using lectures, information discussions, and assignments. The lecture and information discussion methods aimed to make it easier for students to understand the material and issues in learning, while the assignments helped students solve problems and practice critical thinking skills. Based on the validation and field testing, the e-book on environmental science oriented towards conceptual change is suitable for use and has proven valid, practical, and effective.

The validation results show that the developed teaching materials are valid and can be declared suitable for use as a self-learning resource for students of Environmental Science courses. Based on the results of the third validator questionnaire and the student response questionnaire, the criteria assessed from the teaching material development stage were categorized as very practical and effective. This is in accordance with the research (Riastuti & Febrianti, 2021), which shows that the developed teaching material product has a high validity value and can be declared suitable for use as an independent learning resource. Furthermore, the study's results (Sahjat et al., 2025) show that % average validity score of 79% categorizes the e-book as quite valid. The field test results show respondents found the e-book easy to use, with an average practicality score of 3.20 from teachers and 3.00 from students. Integrating PjBL and the Pancasila Student Profile in the e-book facilitates student-centered learning, encourages critical thinking,

collaboration, and creativity, indicating that the developed science e-book is a suitable and effective digital learning resource for improving science education in secondary schools.

The overall development of teaching materials is adequate and does not require Revision. Based on validation and small group classroom trials, these teaching materials can be used as a source of independent learning. The teaching materials that have been developed are a source of independent learning that is specifically designed in accordance with the approach used so that students can discover concepts, procedures, and principles, and can apply them to solve problems given at different levels of understanding in accordance with the curriculum used to achieve the course objectives. Each student has a different level of understanding; therefore, they need to be supported by learning factors, namely internal factors, including physiological and psychological factors, and external factors, including family environment, school/campus environment, and community environment (Ratnapuri, 2021). Furthermore, Febrianti et al. (2023) concluded that the positive response from observers to implementing the environmental science e-book oriented towards conceptual change makes it suitable as a valuable independent learning resource that facilitates lecturers and students during learning activities.

The researchers created the latest teaching material as a conceptual change-oriented e-book for the Environmental Science Course. Lecturers and students can use this e-book product as an independent learning resource for the Environmental Science Course in class. This e-book can stimulate interest in reading, is written and designed for students, explains instructional objectives, flexible learning patterns, structures based on student needs, and final competencies to be achieved, provides opportunities for students to think critically, and accommodates student difficulties.

The final product of the environment-based teaching material has characteristics that include a cover page and an introduction (in the form of suggestions from language experts to improve the e-book product). The development of this teaching material is expected to assist lecturers and students in the lecture process. In addition, other components included in the teaching materials include a table of contents and an introduction (covering environmental science and the objectives of studying Environmental Science). The content of the teaching materials is packaged into a complete unit so that it can be investigated thoroughly by students, independent of other learning media or other learning media, up to date, and user-friendly (covering environmental science material oriented towards conceptual change, including a culture of love for the environment, examples of

environmental problems, and efforts to overcome environmental issues), a bibliography (covering a list of references, sources used to find information and references in compiling teaching materials), and the author's biography (containing the author's biodata).

Teaching materials are a key source and medium in learning, playing a crucial role in the learning. Teaching materials can be used as a guide for educators and students in both independent and face-to-face learning activities. Teaching materials are products designed to align with the approach used, enabling students to discover concepts, procedures, and principles, and apply them to solve a given problem (Sukmawati et al., 2020). Furthermore, teaching materials for critical thinking through scientific writing learning are analyzed based on the form of the teaching material product, the attractiveness of the teaching material product, and the effectiveness of the teaching material product (Aziz et al., 2023). Furthermore, the development of Conceptual Change Text (CCT) from the aspects of content feasibility, presentation feasibility, language assessment, and assessment of multiple representations of chemistry evaluated by several experts, it can be concluded that the developed teaching materials are good and suitable for use in the field with some improvements, with an average validation score of 4. A limited test was conducted on students regarding the developed teaching materials, and the students responded well to the teaching materials because they could help them understand the subject matter (Sukmawati et al., 2020).

Conclusion

Based on the above discussion, this study concludes that the e-book on environmental science oriented towards conceptual change is designed in accordance with the form of a textbook consisting of four components, namely the outside of the book (front cover, spine, back cover), the front of the textbook (title page, foreword page, and table of contents page), the content of the textbook (chapter titles, introduction, material, and assignments), and the section after the content (bibliography page and author biography page). This e-book is valid, practical, and effective, making it suitable as an independent learning resource for students. The linguistic validation results show that this e-book is valid with a score of 0.75. In a small group trial, this e-book was rated practical and effective with a percentage of 95.05%. In a large group trial, this e-book was also rated practical and effective with a percentage of 95.89%.

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Author Contributions

Research concept and research leader, Y.F.; data analysis, Y.F.; resources, Y.F., I.S., R.D.R., R.J., and A.L.; implementation, evaluation, and data collection, Y.F., R.J., and A.L.; review and editing, Y.F., I.S., and R.D.R. All authors have read, reviewed, and approved the published manuscript.

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Conflicts of Interest

The authors declare no conflicts of interest related to this research.

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