Development of RADEC-Based E-Modules Integrated with SETS Approach to Green Chemical Materials

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Article History:
Received: May 23, 2025
Revised: Aug 19, 2025
Accepted: Nov 28, 2025
Online First: Jan 01, 2026

Keywords:
E-Modul,
Green Chemistry,
RADEC,
SETS.

Kata Kunci:
E-Modul,
Kimia Hijau,
RADEC,
SETS.

Abstract: This research is motivated by the lack of interactive teaching materials integrated with learning models and approaches in green chemistry materials. One potential solution is the development of E-Modules based on the RADEC learning model, integrated with the SETS approach to green chemistry materials. This study aims to analyze the needs, feasibility, practicality, and students' responses to the E-Modules developed. This research is a development research with the ADDIE model. The instruments used are the interview sheet, needs questionnaire, material expert and media expert validation sheet, practicality questionnaire, and learner response questionnaire. The subjects of this study consisted of chemistry teachers and students at SMA Negeri 2 Langsa, SMA Negeri 3 Langsa, and SMA Negeri 5 Langsa. The results of the needs analysis showed 71.43% in the needed category, validation by material and media experts, with Aiken's V scores of 0.91 and 0.95, respectively, both very valid; practicality of 90.40% in the convenient category; and student response of 88.43% in the exciting category. Thus, the RADEC-based E-Module, integrated with the SETS approach to green chemistry materials, is highly feasible as a teaching resource in schools.

Abstrak: Penelitian ini dilatarbelakangi oleh kurangnya bahan ajar interaktif yang terintegrasi model dan pendekatan pembelajaran dalam materi kimia hijau. Salah satu solusi potensial yang ditawarkan adalah pengembangan bahan ajar berupa E-Modul berbasis model pembelajaran RADEC terintegrasi pendekatan SETS pada materi kimia hijau. Penelitian ini bertujuan untuk menganalisis kebutuhan, kelayakan, kepraktisan, dan respons peserta didik terhadap E-Modul yang telah dikembangkan. Penelitian ini merupakan penelitian pengembangan dengan model ADDIE. Instrumen yang digunakan adalah lembar wawancara, angket kebutuhan, lembar validasi ahli materi dan ahli media, angket kepraktisan, dan angket respons peserta didik. Subjek penelitian ini terdiri dari guru kimia dan peserta didik di SMA Negeri 2 Langsa, SMA Negeri 3 Langsa, dan SMA Negeri 5 Langsa. Hasil analisis kebutuhan diperoleh 71,43% dengan kategori dibutuhkan, validasi ahli materi dan media dengan skor aiken's V berturut-turut 0,91 dan 0,95 dengan kategori sangat valid, kepraktisan sebesar 90,40% dengan kategori sangat praktis, dan respons peserta didik sebesar 88,43% dengan kategori sangat menarik. Dengan demikian, E-Modul berbasis RADEC terintegrasi pendekatan SETS pada materi kimia hijau sangat layak digunakan sebagai bahan ajar di sekolah.

How to cite:
Nilawati, N., Mauliza, M., & Oktaviani, C. (2026). Development of Radec-Based E-Modules Integrated with Sets Approach to Green Chemical Materials. *Edunesia : Jurnal Ilmiah Pendidikan, 7*(1), 19-42.

https://doi.org/10.51276/edu.v7i1.1304

A. Introduction

The development of information technology has changed all aspects of life. The implication is that every nation, including Indonesia, must adapt to the demands of the times (Novitasari, 2023). One impact of rapid technological development is significant changes and challenges in education (Hasibuan et al., 2023). Digital technology needs to be applied in education to optimise learners' understanding and overcome the limitations of the senses, space, and time (Fitriya et al., 2022). One factor that significantly impacts technological developments in education is the creation and use of teaching materials. Teaching materials are all resources used by teachers to facilitate more effective and efficient learning (Ahmar & Rahman, 2017; Sumiati et al., 2017). Examples of the use of technology in chemistry teaching materials include E-Modules and E-LKPD, which have been widely developed using applications such as Canva and Flipbook. The use of these applications not only supports the effective delivery of material but also helps teachers provide more varied and innovative learning media aligned with the characteristics of 21st-century learning.

E-Modules are teaching materials that are systematically organized, use easy-to-understand language, and are packaged in electronic form to be easy to use and interactive (Komikesari et al., 2020). E-Modules function as learning tools that contain material, methods, limitations, and evaluations, systematically and engagingly designed to achieve the expected competencies at each level of complexity (Elvarita et al., 2020). E-Modules allow learners to master the material independently because they can be accessed anytime, anywhere. E-Modules contain text, images, audio, animation, and video that can create a two-way relationship with the user involving the senses of sight and hearing (Nengsih et al., 2023; Wulansari et al., 2018).

Based on interviews with teachers at SMAN 3 Langsa and SMAN 5 Langsa, it was found that, in green chemistry lessons, teachers reported that the subject was enjoyable for students. However, students tend only to understand the first of the 12 principles of green chemistry, namely waste prevention. This has the potential to lead to the misapplication of the concept, resulting in students being unable to see the interrelationships among principles, difficulty in developing innovative solutions, and irrelevance in dealing with complex environmental problems in society. This is due to several reasons, including the fact that lectures and exercises still dominate learning, so students are less active, get bored quickly, and are less motivated to apply green chemistry concepts in authentic contexts. In addition, the limited availability of green chemistry teaching materials that support integrating green chemistry into everyday life is another reason why green chemistry is considered difficult, as there are no contextual, interactive learning resources that connect green chemistry concepts to everyday applications. Therefore, innovation in the form of E-Modules is needed that not only focuses on green chemistry materials but also on their integration into daily life, including the environment, technology, and society.

To further increase effectiveness, E Modules can be integrated with appropriate models and approaches. This will further support learner engagement, support student-centred learning, maximise mastery of competencies, and encourage differentiation of

https://doi.org/10.51276/edu.v7i1.1304

learning (Hasibuan et al., 2023; Jasmi & Yulkifli, 2024). One learning model that can be used is the RADEC model. The RADEC learning model fits the educational context in Indonesia. This learning model has characteristics that can be a solution to educational problems in Indonesia (Pratama et al., 2019). RADEC stands for its syntax, which consists of read, answer, discuss, explain, and create. The RADEC model can improve creative thinking skills (Suryana et al., 2021; Widyarti et al., 2024), improve critical thinking skills (Pratama et al., 2019; Setyawan et al., 2023), communication skills (Rosmiati et al., 2023), higher-order thinking skills (Maspiroh et al., 2022; Tulljanah & Amini, 2021), students' concept understanding (Harun et al., 2022) and can improve students' multirepresentation (Yohana et al., 2022). This learning model has never been applied in class X chemistry at SMA Negeri 3 Langsa and SMA Negeri 5 Langsa, suggesting an opportunity to develop E-Modules based on the RADEC learning model as an innovation in chemistry teaching materials.

In addition to the learning model, E-Modules can also be integrated with approaches, such as the SETS approach. The SETS (Science, Environment, Technology, and Society) approach integrates and connects the components of science, environment, technology, and society (Hayati et al., 2019; Saragih et al., 2021). The SETS approach in chemistry learning is critical because it integrates science, environment, technology, and society so that it allows students to understand the relationship between chemical concepts and their practical applications in everyday life, and encourages them to interact with relevant social and environmental issues actively (Kustantia et al., 2023; Nugraheni et al., 2023). The SETS approach has been proven effective in creating a more holistic and applicable learning experience for students (Hamdiyah et al., 2024; Kustantia et al., 2023; Nugraheni et al., 2023).

Green chemistry, as one of the materials taught in phase E, is a scientific approach that aims to design chemical products and processes that minimise or eliminate the use and formation of harmful substances. Green chemistry plays an important role in shaping a sustainable future (Zimmerman et al., 2020). Teaching green chemistry to learners is essential to foster awareness and promote sustainable practices among future generations. By incorporating green chemistry into one of the materials taught, learners can learn to design safer chemical processes, understand the importance of reducing hazardous substances, and appreciate the role of chemistry in sustainability (Achu, 2024; Usak, 2024).

The selection of the RADEC learning model is relevant for the development of green chemistry E-Modules because it encourages active learning, critical and creative thinking, in line with constructivist theory and the Merdeka curriculum. The stages of read, answer, discuss, explain, and create help students independently improve their scientific knowledge, social interaction, and the application of green chemistry concepts in everyday life. The E-Module is filled with content based on RADEC syntax combined with SETS (science, environment, technology, society) elements. Packaged in a digital format, the E-Module is easily accessible and visually appealing, with the hope of maximising student engagement in contextual and innovative learning.

The integration of the RADEC learning model with the SETS approach in the E-Module will provide a precise learning flow through five stages: Read, Answer, Discuss,

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Explain, and Create. These stages not only encourage students to read and understand the material but also to process information through the answer stage, discuss it through the discuss stage, explain it again through the explain stage, and produce simple products that reflect their understanding of the concept through the create stage. Meanwhile, the four elements of the SETS approach, namely Science, Environment, Technology, and Society, are integrated into each stage of RADEC. This approach will connect green chemistry concepts with real life. Through the SETS approach, students are invited to see how green chemistry principles, such as waste prevention, the use of renewable raw materials, and design for degradation, are directly relevant to the environment, technological development, and society. The integration of RADEC and SETS is expected to make green chemistry learning more meaningful, contextual, and able to foster students' awareness of the environmental issues they face in their daily lives.

Some previous studies, including that by Yauna et al (2023), showed that RADEC-based E-Modules on atomic structure materials improved students' cognitive abilities and were very helpful for self-study. Furthermore, research by Setyawan et al (2023) found that integrating the RADEC model with the STEAM approach can improve students' critical thinking skills. The research conducted by Norlaila et al (2024) showed that the SETS-based E-Module on chemical equilibrium material increased students' independence and learning outcomes.

This study is directed to explore the actual conditions and needs of chemistry teachers regarding the availability of interactive teaching materials for green chemistry learning in senior high schools. It seeks to examine how far the developed RADEC-based E-Module integrated with the SETS approach meets the criteria of validity in terms of content and media, practicality in classroom implementation, and attractiveness based on students' responses. Furthermore, this study aims to develop innovative digital teaching materials that systematically integrate the RADEC learning model with the SETS approach to support contextual and student-centered learning of green chemistry. Through this development, the study investigates whether the resulting E-Module is feasible, easy to use, and capable of fostering student motivation, engagement, and 21st-century skills, including critical thinking, creativity, and problem-solving. Ultimately, the developed teaching materials are expected to contribute to improving the quality of green chemistry learning and enhancing students' learning experiences and outcomes in accordance with the Merdeka Curriculum.

B. Method

This research is a development research using the ADDIE model (analysis, design, development, implementation, and evaluation). The reason for using the ADDIE development model is that ADDIE is appropriate for developing educational products and other learning resources (Branch, 2009). This research was conducted at Universitas Samudra, SMA Negeri 2 Langsa, SMA Negeri 3 Langsa, and SMA Negeri 5 Langsa, involving two media and material expert validators, 3 grade X chemistry teachers, and 42 grade X students in the even semester of the 2024/2025 academic year. The selection of

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schools was based on several reasons, namely, high schools that have implemented an independent curriculum and high schools that require student-centred teaching materials, namely RADEC-based E-Modules integrated with the SETS approach, as determined by the needs analysis. The students in this study were 10th-grade students enrolled in a green chemistry course.

Data collection in this study included interviews, questionnaires, validation, and documentation. The instruments used include interview sheets, needs analysis questionnaires to determine teachers' needs for the E-Modules to be developed, material and media expert validation sheets to determine the feasibility of the E-Modules that have been developed, practicality questionnaires addressed to teachers, and student response questionnaires. Before being used in data collection, all instruments used are validated by a validator to ensure their validity. The stages of developing this E-Module follow the ADDIE model, which includes analysis, design, development, implementation, and evaluation.

Figure 1. Flow of the ADDIE Model Development

This study employed the ADDIE development model through a systematic and iterative process. The research began with the analysis stage, which involved identifying teachers' needs, examining the applied curriculum, and analysing green chemistry materials to determine the direction of E-Module development. The design stage focused on developing the E-Module outline, selecting appropriate content, formulating learning indicators, and preparing research instruments.

In the development stage, the E-Module was produced based on the approved design and integrated with the RADEC learning model and the SETS approach. Validation instruments were also prepared, and the developed product was evaluated by material and media experts to ensure its validity. The implementation stage involved limited trials with teachers and grade X students to assess the practicality and attractiveness of the E-Module in real learning contexts. Finally, the evaluation stage aimed to refine and improve the E-Module based on feedback obtained from the previous stages, ensuring that the product met the criteria of validity, practicality, and feasibility for classroom use.

Through these stages, the research will produce a valid, practical, and enjoyable RADEC-based E-Module with an Integrated SETS Approach to improve students' understanding of green chemistry material.

Table 1. Instrument for Teacher Interview

No	Aspects
1	Curriculum used
2	Teaching materials and media used
3	Models and approaches used
4	Chemistry learning process in the classroom
5	Facilities and infrastructure

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The interview was addressed to the chemistry teacher of class X. Interviews are used to conduct preliminary studies and to elicit in-depth information from respondents regarding the problems to be studied. The interview type is a semi-open interview, including questions about the curriculum used, learning materials and media used, learning models and approaches, and learning chemistry in the classroom, facilities, and infrastructure.

Table 2. Instrument for teacher needs analysis

No	Aspects	Questions
1	Curriculum	The use of an independent curriculum
2	Use of teaching materials	Teaching materials used
		The need for teaching materials in the form of E-Modules
3	RADEC Model	The use of learning models in learning chemistry
		The use of RADEC learning models in learning chemistry
4	SETS Approach	The use of approaches in learning chemistry
		The use of SETS approaches in learning chemistry
5	Learning Process	The difficulty of students learning chemistry
6	Materials	Material that is difficult for students to understand
		Green chemistry material

(Source: modified from (Putri et al, 2024)

This needs analysis questionnaire instrument is addressed to class X chemistry teachers. Aiming to find out the needs of teachers regarding the development of RADEC-based E-Modules Integrated with the SETS Approach on green chemistry material.

Table 3. Instrument for Material Expert Validation

No	Aspects of Assessment	Indicators
1	Conformity with learning outcomes (CP)	Learning indicators are in accordance with the TP
2	Accuracy of Material	The concepts and definitions presented in the E-Module do not lend themselves to many interpretations.
		Data, images and illustrations used in the E-Module are in accordance with the material presented.
		The material in the E-Module is presented in a sequential order.
		Chemical notations, symbols and formulas are presented correctly.
		The practice questions in the E-Module align with the concepts and are effective for improving students' competence.
3	Presentation technique	The E-Module content is systematically presented in accordance with the RADEC model.
		The E-Module content is systematically presented in the SETS approach format.

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No	Aspects of Assessment	Indicators
		The material is presented from easy to difficult.
		The material is presented from concrete to abstract
4	Presentation of Learning	E-Modules developed can be used as independent teaching materials.
		E-Modules developed do not require other textbooks as learning support (stand-alone)
		E-Modules developed have high adaptability to the development of science and technology (adaptive)
		The presentation of material in the E-Module is dialogical, which allows students to communicate with the author (user-friendly)
5	Supporting Presentation	The E-Module contains evaluations that assess students' understanding. The module contains instructions for using the E-Module.
		The E-Module includes an evaluation that assesses students' understanding.
		The E-Module includes answer keys and assessment guidelines.
		The E-Module includes a summary of the material to reinforce concepts.
		The E-Module's content includes a glossary arranged alphabetically.
		The content of the E-Module contains a bibliography as reference material for writing the module
6	Readability	The language used is appropriate to the students' level of thinking development.
		The language used is easy to understand and is not multi-interpretive.

(Source: modified from (Pangestu, 2021)

The material expert validation instrument aims to ensure the validity of the material used in the E-Module. Through the material expert assessment, researchers will get revisions and suggestions to improve the quality of the E-Module.

Table 4. Instrument for Media Expert Validation

No	Assessment Aspects	Indicators
1	E-Module Size	The size of the E-Module is in accordance with ISO standards (A4 21 cm x 27 cm)
2	E-Module Cover Design	The layout elements on the front and back covers form a unified whole.
		The colour of the layout elements is harmonious and displays good contrast.
		The E-Module cover illustrations illustrate the contents of the E-Module

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No	Assessment Aspects	Indicators
3	E-Module content design	Placement of margins, distance between text, shape, colour, and size is proportional.
		Placement of titles, subtitles, illustrations, and image captions does not interfere with understanding.
		Placement of titles, subtitles, page numbers, Placement of titles, subtitles, page numbers, page numbers, blank spaces, proportional
		Placement of proportional illustrations/images
4	Typography of E-Module Content	The font type and size are proportional.
		Typeface can make reading easier for students. Spacing between lines of standard text arrangement
		Spacing between letters is standard.
		Numbering is correct and consistent
5	Application Device Access	The Heyzine Flipbook application can be operated easily
		The QR codes and links listed are easily accessible.
		The Heyzine Flipbook application opens properly in all browsers.

(Source: modified from (Pangestu, 2021)

The media expert validation instrument aims to ensure the validity of the developed media. Through assessments by media experts, researchers will receive revisions and suggestions to improve the quality of E-Modules.

Table 5. Instrument for Teacher Response

No	Aspects	Indicators
1	Product Design	The E-Module's appearance is attractive.
		The harmony of the use of colour
2	Effectiveness	The material presented is in accordance with the TP.
		The material presented is in accordance with the learning indicators.
		The material presented in the E-Module is appropriate for the learners' ability levels.
		The material presented in the E-Module is complete.
		The examples given are in accordance with the material.
		Clarity of instructions in filling out the questions
		The Heyzine Flipbook application is easy to access and use
3	Language	The language used is easy to understand
		The writing in the E-Module is presented clearly.
		The material uses simple language.

(Source: modified from (Lukitaningrum, 2016)

This instrument is used to assess the E-Modules developed as teaching materials. There are three aspects of assessment: product design, effectiveness, and practical feasibility of RADEC-based E-Modules integrated with the SETS approach for green chemistry materials.

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Table 6. Instrument for Student Responses

No	Aspects	Indicators
1	Design	Attractive E-Module display
		Harmonious use of colour
		The Heyzine Flipbook application is easy to access and use
2	Material content	Instructions for use are easy to understand
		Clarity of sentences in the material
		Evaluation questions are in accordance with the material.
		The use of E-Modules makes it easier to understand the material

(Source: modified from (Desi et al., 2022)

The learner response questionnaire sheet is given to learners to assess the product's attractiveness. This instrument is used to gather feedback from students who are potential users of the product.

The scale used is the Guttman scale (Yes / No) for the needs analysis questionnaire and Likert scale for expert validation, practicality questionnaire, and learner response questionnaire, with a scale range of 1-4, with the following criteria:

Table 7. Likert Scale Scoring

Score	Description
4	Strongly agree
3	Agree
2	Disagree
1	Disagree

Interview data were analysed using a descriptive qualitative approach. The data obtained were analysed through the stages of data reduction, data presentation, and conclusion drawing to obtain an overview of the needs for developing teaching materials. The needs analysis questionnaire uses a Guttman scale (Yes/No). If the answer is "Yes", the score is 1; if the answer is "No", the score is 0. The score is then calculated using the percentage formula as follows:

$$P_s = \frac{S}{N} x100\%$$

Description:
P_s = percentage of questionnaire data
S = number of scores obtained
N = maximum number of scores
The calculation results are then interpreted into the following criteria:

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Table 8. Criteria for Scoring the Needs Analysis Questionnaire

Percentage (%)	Interpretation Criteria
76 – 100	Strongly needed
75 – 51	Needed
50 – 26	Moderately needed
≤ 25	Not needed

(Source: Winarni et al, 2014)

To obtain feasibility data, the validation questionnaires of material experts and media experts were calculated using Aiken's V formula as follows:

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

Description:
S = r - lo
lo = lowest validity assessment number
c = highest validity assessment lift
r = lift given by validators
n = number of assessors
The validity category based on Aiken's V coefficient is interpreted as follows.

Table 8. Criteria Based on Aiken's V Scale

Aiken's V value range	Validation criteria
0,8 < V	Highly valid
0,4 < V ≤ 0,8	Valid
V ≤ 0,4	Less valid

(Source: Yunika et al., 2020)

Data on teacher responses to the RADEC-based E-Module, integrated with the SETS approach to green chemistry materials, were analysed quantitatively using the following formula.

$$Practicality\ (P) = \frac{number\ of\ scores}{maximum\ score} x100\%$$

After obtaining the percentage of practicality, the value is then converted into qualitative data with the product's practicality criteria as follows:

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Table 9. Product Practicality Criteria

Percentage (%)	Interpretation criteria
81 – 100	Very practical
71 – 80	Practical
61 – 70	Quite practical
<60	Less practical

The results of the attractiveness questionnaire sheet that students have filled in as respondents are then analysed quantitatively with the following formula:

$$Percentage\ of\ attractiveness = \frac{nuber\ of\ scores\ obtained}{maximum\ score} x\ 100\%$$

After obtaining the percentage of attractiveness, the value is then converted into qualitative data with the following criteria for product attractiveness:

Table 10. Learner response criteria

Percentage (%)	Interpretation criteria
80 – 100	Very interesting
66 – 79	Interesting
56 – 65	Quite interesting
46 – 55	Less interesting
≤45	Very little interesting

(Source: Yanti & Sari, 2021)

C. Result

Analyze Stage

a. Needs Analysis

The needs analysis was carried out in a structured manner by preparing questions to obtain the expected information. Data collection was conducted by administering a needs analysis questionnaire to chemistry teachers at SMA Negeri 2 Langsa, SMA Negeri 3 Langsa, and SMA Negeri 5 Langsa. The results of the needs analysis can be seen in Table 11.

Table 11. Results of the Needs Analysis of Chemistry Teachers in Grade X

Aspects	SMAN 2	SMAN 3	SMAN 5
Curriculum	66,67%	76,19%	71,43%
Use of Teaching Materials			
RADEC Model			
SETS Approach			
Learning Process			
Materials			
Average	71,43%		
Interpretation Criteria	Needed		

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Based on the results of the needs analysis in Table 11 above, it shows that the development of RADEC-based E-Modules integrated with the SETS approach for green chemistry materials is needed.

b. Curriculum Analysis

Based on interviews with teachers at SMA Negeri 2 Langsa, SMA Negeri 3 Langsa, and SMA Negeri 5 Langsa, information was obtained that the curriculum used was the independent curriculum. This independent curriculum has been applied for 2 years in grades X and XI. Meanwhile, class XII still uses the K13 curriculum.

c. Material Analysis

At this stage, an analysis of the material to be included in the E-Module is conducted. The analysis was carried out by looking at the curriculum used, namely the independent curriculum. The results are presented as coverage of the material taught in class X in phase E and the learning outcomes students must achieve.

Design Stage

a. E-Module Outline Design

The outline preparation aims to organise ideas systematically, making the E-Module developed more structured. It starts with creating a flowchart, which is then developed into an E-Module outline. The flowchart will outline the content flow in the E-Module. The flowchart is shown in Figure 1.

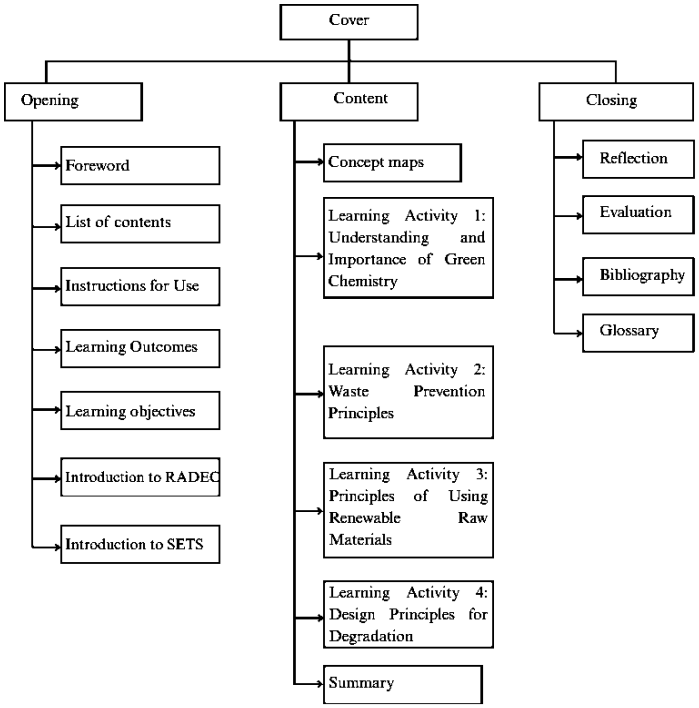

Figure 1. Flowchart of E-Module Design

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In this section, the layout of the E-Module is also determined, including the type of font used (Bree Serif, Bitter, Times New Roman), font size (learner activity title is 35, sub title is 20, content is 14), spacing (1.7), paper size (ISO standard: A4), page numbers (the opening section uses Roman numerals, the contents and closing pages use numbers 1,2,3, etc.) and the location of the page number is located at the bottom center.

b. Selecting high school chemistry materials

The material chosen by researchers is green chemistry material in phase E of class X SMA. The basis for selecting this material is the results of the initial interview and the needs analysis.

c. Determining Material Indicators

In determining material indicators, first formulate the learning objectives and their flow. The objectives and learning objectives flow are compiled based on the learning outcomes of phase E. Then, the material indicators are determined. The material indicators are that students are able to describe the meaning and importance of green chemistry, students are able to make infographics about green chemistry, students are able to understand the importance of the principle of "prevention" in green chemistry and its impact on the environment, society, and technology, students are able to design and create simple products that apply the principle of "prevention" to minimize waste and negative impacts on the environment, students are able to understand the importance of the principle of "using renewable raw materials" and its impact on the environment, society, and technology, learners are able to design and create simple products that use renewable raw materials to minimize the use of fossil resources and negative impacts on the environment, learners are able to understand the importance of the principle of "design for degradation" in green chemistry, and analyze its impact on the environment, society, and technology, and learners are able to design and create simple chemical products or processes that consider the principle of "design for degradation.

d. Designing Research Instruments

The instruments developed in this study included material expert validation instruments, media expert questionnaires, teacher practicability questionnaires, and student response questionnaires on the attractiveness of E-Modules. The material expert validation instrument consists of 6 aspects: suitability for TP, accuracy of the material, presentation techniques, presentation of learning, supporting presentation, and readability. The media expert validation instrument consists of the following aspects: E-Module size, E-Module cover design, E-Module content design, E-Module typography, and application device access. The practicality instrument for teachers consists of aspects of product design, effectiveness, and language. Meanwhile, the learner response instrument comprises two aspects: the design and the content of the material.

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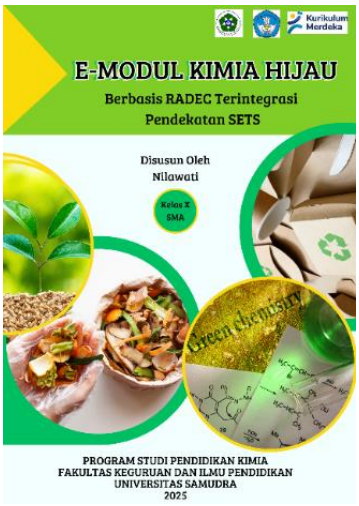
Development Stage

At this stage, the approved outline is developed into a complete E-Module. E-Module development uses Canva and Heyzine Flipbook applications. The results of the development stage are described as follows.

a. Preparation of E-Modules

The E-Module was developed using the Canva application. The preparation starts from making the front cover, design template, opener, content, cover, and back cover. The selection of Canva as an application for designing E-Modules is because it offers a variety of professional templates, intuitive editing tools, and an easy-to-use interface, enabling the creation of visually appealing E-Modules that can be customised as needed. The results of the E-Module development are presented as follows.

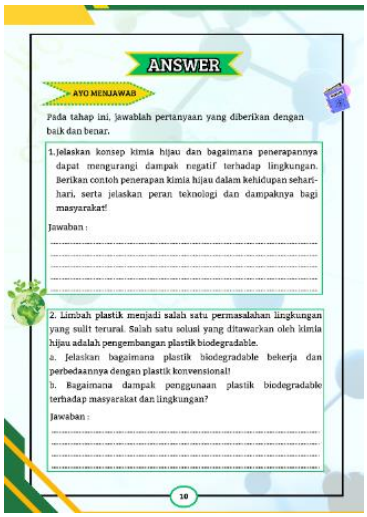


Front Cover

CP and TP

Read Stage

SETS Elements



Answer Stage

Discuss Stage

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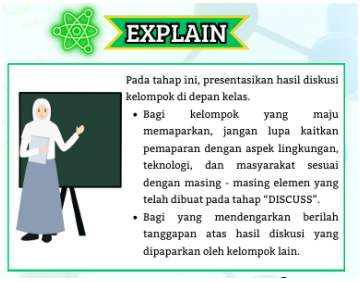

Explain Stage

Create Stage


Back Cover

Figure 2. Display of the Developed E-Module

b. E-Module Validation

Product validation aims to ensure the developed product is valid and can be implemented in schools. The validation carried out is material expert validation and media expert validation, totalling two people. The results of the validation of material experts and media experts are presented in Tables 13 and 14.

Table 13. Material Expert Validation Results

No	Aspects	Aiken's V	Interpretation
1	Conformity with TP	1	Very valid
2	Accuracy of the material	0,89	Very valid
3	Presentation technique	0,79	Valid
4	Presentation of learning	1	Very valid
5	Supporting presentation	1	Very valid
6	Readability	0,78	Valid
	Average	**0,91**	**Very Valid**

Table 14. Media Expert Validation Results

No	Aspects	Aiken's V	Interpretation
1	E-Module Size	1,00	Very Valid
2	E-Module Cover Design	0,94	Very Valid
3	Desain isi E-Modul	0,94	Very Valid
4	Tipografi isi E-Modul	1,00	Very Valid
5	E-Module content design	0,89	Very Valid
	Average	**0,95**	Very Valid

Implementation Stage

At this stage, a limited trial was conducted with chemistry teachers and grade X students. The results of the practicality questionnaire and students' responses are shown in Tables 15 and 16.

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Table 15. Results of Teacher Practicality Questionnaire

No	Aspects	Percentage (%)	Criteria
1	Product Design	91,67	Very practical
2	Effectiveness	90,63	Very practical
3	Language	88,89	Very practical
	Average	90,40	Very practical

Table 16. Results of the Learner Response Questionnaire

No	Aspects	Persentage (%)	Criteria
1	Design	90,48	Very practical
2	Material content	86,43	Very practical
	Average	88,61	Very practical

Evaluation Stage

Evaluation in this study was carried out at the design, development, and implementation stages. The goal is that the product developed is valid and feasible for use in schools. At the design stage, the prepared outline can proceed to the development stage. Based on the validation results, the E-Module was found to be highly valid across both the material and media. Based on the results of the practicality questionnaire, the E-Module is declared practical in terms of design, effectiveness, and language. Based on students' responses, the developed E-Module meets the criteria for being very interesting as teaching materials.

D. Discussion

The RADEC-based E-Module, integrated with the SETS approach to green chemistry, is an electronic chemistry teaching material developed in Canva and presented as a Heyzine Flipbook to provide a visual experience similar to a physical book. This E-Module aims to increase the effectiveness and attractiveness of learning and to promote students' active participation in green chemistry learning at school. Based on the analysis results, teachers need interactive teaching materials to support collaboration. The underutilization of E-Modules creates opportunities to develop them as alternative teaching materials. In addition, the RADEC learning model is widely known and used in research schools, and the SETS approach is considered relevant to green chemistry learning. This shows the importance of developing a RADEC-based E-Module integrated with SETS that aligns with the Merdeka Curriculum, as it can encourage independent learning, relate the material to real life, and support the formation of the Pancasila learner profile. Thus, this E-Module has the potential to be an innovative solution for green chemistry learning, increasing students' motivation, critical thinking, and problem-solving skills (Lestari et al., 2023; Sutantri et al., 2023).

https://doi.org/10.51276/edu.v7i1.1304

The E-Module was developed through systematic stages and has undergone validity testing by experts, namely media experts and subject matter experts. The development of the E-Module requires careful attention to various design and structural elements. Key considerations include selecting the format, typography, visual appeal, and the systematic arrangement of content. These elements ensure that the E-Module is not only informative but also attractive and accessible to learners. The structure of the E-Module must include key components such as an introduction, main section, and conclusion, which are organised systematically to facilitate understanding (Daryanto, 2013). In addition, the preparation and development of E-Modules must also take into account the characteristics of the module itself, namely self-instruction, self-contained, stand-alone, adaptive, and user-friendly (Daryanto, 2013).

Based on the results of media and material expert validation, the RADEC-based E-Module integrated with the SETS approach received a highly valid rating with Aiken's V values of 0.95 and 0.91. This indicates that the learning objectives, the completeness of the material, and the language used are appropriate for 10th-grade students. The input provided by the validators was generally technical, such as consistency in word usage. Meanwhile, regarding media, the assessment found that the appearance, interactivity, and navigation in the e-module were appropriate. Media experts found that interactive flipbooks supported student engagement because they included multimedia features (text, images, and exercises). The feedback provided focused on adjustments to the layout and colour consistency to make it more attractive, which were corrected during the revision stage. These results are in line with previous studies, which show that digitally designed interactive teaching materials can increase motivation and conceptual understanding and provide an interactive learning experience (Alia et al., 2023; Syahfitri & Safitri, 2024).

Based on the results of practicality and attractiveness, the developed E-Module was found to be very practical and very attractive, with percentages of 90.40% and 88.43%, respectively. The practicality results show that the E-Module is easy to use, aligned with the learning objectives, and can assist teachers in delivering green chemistry material. The high attractiveness results indicate that the RADEC-based E-Module, integrated with the SETS approach, motivates students to be more active in reading, discussing, and creating works. Meanwhile, the SETS approach makes learning feel real by connecting science with the environment, technology, and society. This finding is reinforced by research by Fatayah et al (2025), which shows that an interactive E-Module can increase students' motivation, interest, and learning outcomes.

The integration of the RADEC (Read, Answer, Discuss, Explain, Create) model with the SETS (Science, Environment, Technology, Society) approach in the green chemistry E-Module provides a more comprehensive learning experience. This is because students not only learn green chemistry theoretically but also relate it to the environment, technology, and its impact on society. In the Read stage, students are directed to read material directly related to SETS aspects, such as reading about biopac, briquettes, and ecoenzymes. In the

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Answer stage, the questions provided emphasise integration with the four elements of SETS. For example, the following are questions in the Answer section:

Science	:	What is biomass, and how does it differ from fossil fuels in terms of chemical composition and carbon cycle?
Enviroment	:	How can the concept of zero waste be applied in the use of biomass as an energy source?
Technology	:	In some areas, agricultural waste such as rice husks and corn cobs is often discarded. What simple technologies can communities or schools use to process this waste into alternative energy sources?
Society	:	Many farming communities are beginning to switch from chemical fertilisers to organic fertilisers derived from biomass waste. How can this transition benefit farmers and communities in the long term?

Next, in the Discuss stage, the SETS approach is reinforced: students discuss real issues facing society, such as household waste pollution, and relate them to solutions based on green chemistry principles. In the Explain stage, the four SETS elements are integrated, and students present the results of their discussions, emphasising the interrelationships among scientific concepts, environmental impacts, the use of technology, and their contributions to society. Finally, in the Create stage, students actualise all the knowledge they have gained from the beginning of the learning stage and integrate the four SETS elements through a project. Examples include making simple products from renewable materials, creating infographics about green chemistry, or making simple products such as eco-enzymes from organic waste materials.

Thus, the integration of the RADEC learning model with an approach that encourages students to think at a higher level (HOTS), connects scientific concepts with environmental issues, technological solutions, and impacts on society, develops 21st-century skills, realises knowledge into tangible products, and increases awareness of the environment makes green chemistry learning more comprehensive, applicable, and meaningful.

Overall, the developed E-Module meets the criteria of feasibility, practicality, and attractiveness as teaching material. These results indicate that the content and presentation of the material are in accordance with learning standards and can be easily used by teachers and students. Thus, the E-Module is suitable for integration into the school learning process.

E. Implication

The implication of this study is the availability of RADEC-based E-Modules integrated with the SETS approach as digital teaching materials for green chemistry. These E-Modules can serve as an alternative to green chemistry learning, increasing students' motivation, understanding, and various skills. Additionally, its flexible format and compatibility with various devices allow implementation in schools with varying technological resources, enabling both online and offline use. Teachers can use this E-Module as a primary or supporting learning resource to increase student engagement in

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green chemistry. Meanwhile, students can use the E-Module to improve their understanding, skills, and learning experiences. However, challenges such as limited technological infrastructure, teacher readiness, and differences in students' ability to use digital teaching materials need to be anticipated through mentoring, training, and infrastructure support.

F. Limitation and Suggestion for Further Research

This study is still limited to small-scale trials and therefore does not represent the diversity of school conditions. Technical obstacles, such as limited equipment, internet connectivity, and teachers' and students' readiness to use digital teaching materials, also pose challenges. Therefore, further research is recommended on a larger scale across diverse school conditions, while also developing interactive features, integrating with online platforms, and applying the RADEC-based E-Module integrated with SETS to other chemistry materials, to test its effectiveness more comprehensively.

G. Conclusion

This study shows that the RADEC-based E-Module, integrated with the SETS approach in green chemistry materials, is highly valid, practical, and engaging, making it suitable for use in the school learning process. The developed E-Module can increase student motivation, encourage activity, and provide a more interactive learning experience in line with the independent curriculum. Through this research, digital teaching materials are available to support green chemistry learning in schools with varying conditions, both those with adequate and limited technological facilities. Although the trials are still limited, further research is needed on a broader scale, with the addition of interactive features and integration with online platforms, to optimise the potential of this E-Module for green chemistry learning in schools.

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https://doi.org/10.51276/edu.v7i1.1304

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