



# Development of a web-based digital platform through the green education model on green chemistry material

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## ABSTRACT

The Green Education model emphasizes contextual learning with real-world environmental issues, encourages collaboration, and encourages students to think critically in solving environmental problems such as pollution, waste, and energy use. This study aims to determine the conceptual and procedural feasibility according to material and media experts, teacher assessments, and student responses to the interactive learning website developed using the Green Education model for green chemistry. This research is a developmental study using the Lee & Owens model. Data collection methods used questionnaires and interviews. Data analysis techniques used were qualitative data analysis based on comments and suggestions, and quantitative data analysis based on average response scores and percentages. The results of this study demonstrated feasibility based on a Likert scale, with a score of 4.5 (very feasible) from material experts, 4.57 (very feasible) from media experts, 4.5 (very feasible) from teachers, and 87.07% (very feasible) from student responses. Based on the development and research results, it can be concluded that the interactive learning website using the Green Education model for green chemistry is conceptually and procedurally feasible as a teaching medium for chemistry learning.

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## INTRODUCTION

The Sustainable Development Goals (SDGs), a sustainable development goal to be achieved by 2030, are designed to address all existing societal issues. Quality education play a crucial role in shaping country's economic future (Azzahra et al., 2024). Chemistry is a subject that needs to be taught in a way that involves students' abilities and thinking skills, so that students can understand well and consider chemistry as a process and its results (Wannesia et al., 2022; Rahman & Mauraji, 2025). Chemistry can essentially be seen as a process and a product, however, in practice, chemistry learning is only theoretical, resulting in a lack of development of science process skills (Supatmi, 2022; Sitompul et al., 2024).

Chemistry education plays a vital role in developing students' understanding of scientific concepts that are closely connected to daily life. However, growing global environmental concerns necessitate a shift in instructional approaches one that extends beyond conceptual comprehension to the cultivation of ecological awareness (Saba, 2024; Kustiarini et al., 2024). Green chemistry offers a relevant framework, emphasizing the design of chemical products and processes that minimize or eliminate the use of hazardous substances (Sitompul et al., 2025a). Despite its significance, research indicates that the integration of green chemistry in school instruction remains limited and insufficiently embedded within the curriculum (Karpudewan et al., 2015).

The Green Education model is a learning approach that emphasizes the systematic integration of environmental sustainability values into the educational process. In the context of chemistry learning, this model guides students to understand chemical concepts not only theoretically but also from their impact on the environment, health, and sustainability (Mukhlisin, 2022; Azizah et al., 2025). Green Education helps students develop critical thinking skills related to ecological issues while instilling an awareness that every chemical process has environmental consequences that must be managed responsibly (Tilbury, 2011). Thus, chemistry learning is no longer simply about reactions or molecular structures, but also about how chemical applications can be designed and used to reduce waste, minimize toxicity, and support more efficient resource management in accordance with the principles of green chemistry (Perdana, 2024).

Advancements in technology further highlight the potential of digital media as an effective learning solution. Web-based platforms can facilitate visualization, interaction, and flexible access to instructional content. Heggart & Yoo (2018), note that digital technologies enhance student motivation, conceptual mastery, and independent learning. Yet, existing instructional media rarely incorporate sustainability principles explicitly, particularly within green chemistry materials, which require strong contextual grounding (Zaimina & Munib, 2025).

A suitable approach to address this gap is the Green Education model, which integrates sustainability values, environmental ethics, and ecological literacy into the learning process (Muhyidin et al., 2025; Khasanah et al., 2025). This model encourages students to recognize the interconnection between scientific knowledge and environmental impact, thereby supporting more environmentally responsible decision-making (Purba et al., 2015). Evidence demonstrates that sustainability-oriented education can strengthen students' environmental literacy and foster pro-environmental behavior (Barth et al., 2016).

Given this context, the development of a web-based digital platform grounded in the Green Education model for green chemistry instruction is both relevant and necessary. Beyond addressing the scarcity of contextualized learning media, such innovation aligns with 21st-century learning demands and supports the SDGs, particularly Goal 4 (Quality Education) and Goal 13 (Climate Action). By providing an engaging, interactive, and sustainability-rich digital platform, this initiative is expected to improve student understanding while simultaneously nurturing ecological awareness.

## RESEARCH METHODOLOGY

This type of research is research and development (R&D). The resulting product is an interactive chemistry learning media in the form of a chemistry learning website on Green Chemistry material in grade 10 of high school using the Green Education model. In this study, the development model used is the Lee & Owens (2004) development model. This development model consists of five stages: assessment and analysis, design, implementation, development, and evaluation.

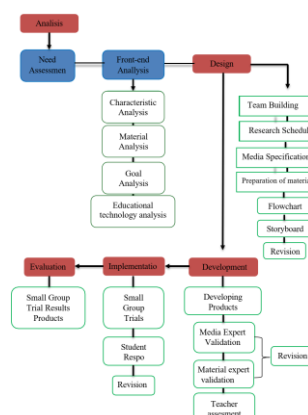


Figure 1. Development procedures

Based on the development procedures above, it can be seen that the Lee & Owens development model chooses 5 stages, namely analysis, design, development, implementation and evaluation.

### Analysis

The analysis phase is carried out to identify and determine student needs in the learning process and gather information related to the Green Education-oriented website product to be developed. The steps taken in this first phase include needs analysis, student characteristics analysis, material concept analysis, learning objectives analysis, and educational technology analysis.

### Design

This research planning was carried out with a product design which will then be used as teaching material in the form of an interactive learning website through the Green Education model on the Green Chemistry material. The product development design plan is as follows:

- Team Formation, developing this interactive learning website certainly requires a team with distinct tasks and roles in the product development process to ensure a high-quality product and optimal results. The team building components for this development process include: (1) Developer; (2) Validator (media expert and material expert); (3) Practitioner validator (chemistry teacher); (4) Respondents/users (Grade X high school students).
- Research Schedule, research, design, and development are processes that create products with the goal of high quality. Therefore, developers and their teams need to develop a detailed, step-by-step schedule to accurately measure product development progress.
- Media Specifications, the media specifications here are an explanation of elements such as themes, writing style combinations, grammar, standard text, animation and music.
- Structure of Matter, the material presented in the product is structured based on learning principles and objectives in accordance with the independent curriculum, which consists of CP, TP which are guided by the chemical ATP used by the school.
- Flowchart Creation, *flow chart* A flowchart is a depiction of the flow that will be displayed in the product being developed. The purpose of creating a flowchart in the development of an interactive learning website is to serve as a primary guideline for developers, as well as a reference for the various components that will be included in the interactive learning website product being developed.
- Storyboard Making, the interactive learning website design is accomplished through the creation of a storyboard, essentially a continuation of the flowchart process. The storyboard also serves as the basis or benchmark for creating an interactive Green Education learning website for green chemistry instruction. The storyboard displays a design for the interactive

learning website, complete with information about the interactive learning website's pages.

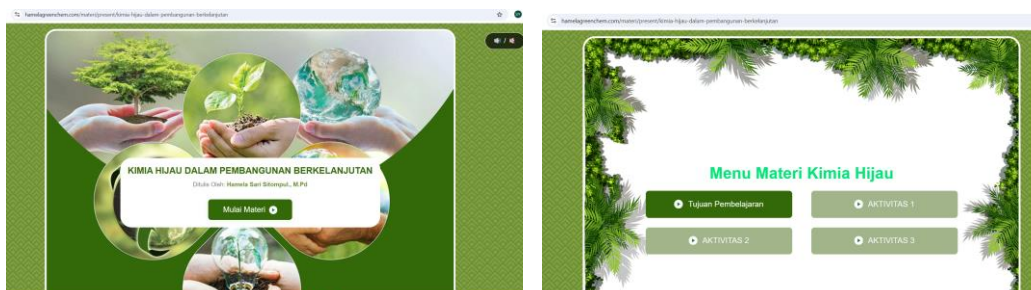


Figure 2. Learning website appearance

- g. Evaluation at this design stage aims to refine the existing design to make it even more high-quality and attractive. This evaluation is conducted through discussions with the supervisor and colleagues..

### Development

The development stage aims to realize the product design or manufacture the product previously conceived in the design stage. In this stage, researchers develop the product using Google Sites.

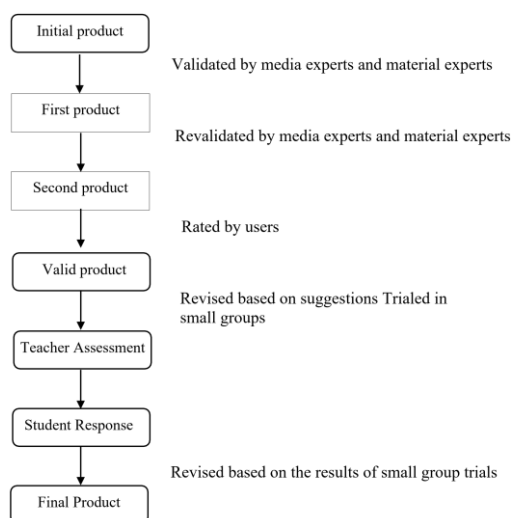


Figure 3. Development stages

### Implementation

Stage Implementation is the concrete stage of implementing the interactive learning website product using the previously developed Green Education model. During this stage, the product will be tested **directly with students to obtain data on its quality**.

### Evaluation

The evaluation phase aims to determine whether the previously developed interactive learning website using the Green Education model is successful and meets expectations. This is a summative evaluation, analyzing student responses as a product evaluation.

In this development research, data collection is carried out in stages and requires measuring tools known as instruments. The data collection instruments used in this study include interview sheets, material expert validation sheets, media expert validation sheets, teacher

assessment sheets, and student response sheets. Once the data is collected, it will be analyzed based on the assessment of the needs instrument, media expert validation instrument, material expert validation instrument, teacher assessment instrument, and student response instrument.

## RESULTS AND DISCUSSIONS

The result of this development research is a teaching material in the form of an interactive learning website using the Green Education model for Green Chemistry material, developed using a website. The resulting product can be accessed online using a computer/laptop or smartphone, making it easy for students to access.

### Validation Stage

The created product was then validated by a team of experts, consisting of material experts and media experts, to determine its suitability for testing. The evaluated product was then revised based on the team's suggestions and comments. The revisions and improvements made to the interactive learning website using the Green Education model are as follows:

- a. Media Expert Validation was conducted under direct guidance, with the researcher explaining the media they had designed. The media expert then assessed and provided suggestions and comments on the product. These suggestions and improvements will serve as primary data for further refinement.

**Table 1.** First media expert validation results

Assessment Aspects	No.	Indicator	Score	Comment
Simplicity	1	Website applied to user-friendly media	4	Website easy to use
	2	Website which is applied to media support on various devices	5	Website which is implemented supported by various device
	3	Website which is used for interactive media according to student characteristics	4	It is in accordance with student characteristics
	4	Use of short, concise and easy sentences understood	4	There are some sentences that need to be changed
Integration	5	The order of presentation between pages is correct	4	More enlarged and arranged again
	6	Images and explanations support each other	3	Plus an explanation below the image in the material
Emphasis Color	7	Videos, animations, and text applied to each page have emphasis	3	Add a video, if possible a homemade video
	8	Color gradation conformity	4	Focus & consistency on color
Form	9	Combination of writing and background	3	There are some parts of the writing that still overlap
	10	Animations and images that used to attract	4	Pay attention again
	11	The type and size of the letters are easy to read	4	Be consistent in the type of letters used
	12	Clarity in the use of chemical symbols	4	It's just right
Balance	13	Animation and image size matching	3	Pay attention again, don't make it too big or too small.
	14	The layout of images, animations and text on each page is balanced.	3	Needs to be reviewed
Total Score			52	
Average			3.71	
Category			Worthy	

The suggestions received from the media expert will serve as guidelines for researchers to improve the interactive learning website oriented toward Chemo-Entrepreneurship. Therefore, the researchers conducted a second validation stage based on the media expert's suggestions, as follows:

**Table 2.** Second media expert validation results

Assessment Aspects	No	Indicator	Score	Comment	
Integration	1	Website which is applied for easy-to-use media	4	Website easy to use	
	2	Website which is applied to media support on various devices	5	Website which is implemented supported by various devices	
	3	Websites used for interactive media according to student characteristics	4	It is in accordance with student characteristics	
	4	Use of concise, concise and easy to understand sentences	5	Already repaired	
	5	The order of presentation between pages is correct	5	The arrangement is correct	
	6	Images and explanations support each other	4	The explanation in the picture is appropriate	
	Emphasis	7	Videos, animations, and text applied to each page have emphasis	5	Fixed as per suggestion
		8	Color gradation conformity	5	Focus & consistency on color is appropriate
	Color	9	Combination of writing and background	4	Fixed as per suggestion
		10	The animation and images used are interesting	5	Images and animations are appropriate
	Form	11	The type and size of the letters are easy to read	5	It is correct and consistent
		12	Clarity in the use of chemical symbols	4	Already correct
		13	Animation and image size matching	5	It's just right
		14	The layout of images, animations and text on each page is balanced.	4	The layout ratio is appropriate
<b>Balance</b>					
Total Score		64			
Average		4.57			
Category		Very Worthy			

Based on this score, the media validator stated that the interactive learning website using the Green Education model was good and worthy of being tested in schools.

- b. Subject Matter Expert, validation by subject matter experts was conducted through direct guidance, where the subject matter experts observed and studied the interactive learning website product using the Green Education model designed by the researchers. The subject matter experts then assessed and provided suggestions and comments on the product. These suggestions and improvements will serve as primary data for further refinement.

**Table 3.** First material validation results

Assessment Aspects	No	Indicator	Score	Comment
Format	1	The appeal of presenting material in the media	3	More images need to be added to the material
	2	Presentation systematics material in the media	4	It is in accordance with reference
	3	Suitability of material with CP and TP	3	It is necessary to review the CP and TP of the material listed again
	4	Suitability of the material with indicators and objectives	3	Needs to be fixed
	5	Ease of understanding material in the media	4	It's good enough
	6	Suitability to student characteristics	4	Add more real examples
	7	Level of depth of material presentation	3	Needs a little adjustment
	8	Suitability of the questions used	4	It is necessary to study the questions to make them more HOTS
Contents	9	The ability of images and animations in general material to visualize chemical concepts	3	It is necessary to examine the images that have been included
	10	The material can be applied in life	4	Project Green Education is suitable and easy to implement
Language	11	Standardity of the language used	4	It's right

Assessment Aspects	No	Indicator	Score	Comment
	12	Ease of understanding the language used	4	Already correct
Total Score			43	
Average			3.58	
Category			Worthy	

Cognitive theory plays a significant role in the practical application of the Green Education approach. By providing understanding (usefulness, what functions are performed), it will influence students' attitudes when applying material associated with the Green Education approach, so that the material associated with the Green Education approach will be applied well. Therefore, the material contained in this media needs to be structured using a certain pattern or logic, from simple to complex. Next, the developer continues to the second validation stage by material experts based on suggestions from material experts which can be seen below:

**Table 4.** Second material validation results

Assessment Aspects	No.	Indicator	Score	Comment
Format	1	The appeal of presenting material in the media	4	The material presented is much more interesting
	2	Systematic presentation of material in the media	5	The presentation of the material is systematic
	3	Suitability of material with CP and TP	4	Has been in accordance with CP and TP
	4	Suitability of material with indicators and objectives	4	It has been appropriate
	5	Ease of understanding material in the media	5	The material presented is easy to understand
	6	Suitability to student characteristics	5	It has been appropriate
	7	Level of depth of material presentation	4	The examples presented make the material more in-depth, but need to be reviewed further.
	8	Suitability of the questions used	4	Better
Contents	9	The ability of images and animations in general material to visualize chemical concepts	5	Has been appropriate and visualized green chemistry material
	10	The material can be applied in life	5	Project Green Education is suitable and easy to implement
Language	11	Standardity of the language used	5	It's right
	12	Ease of understanding the language used	4	Already correct
		Total Score	54	
		Average	4.5	
		Category	Very Worthy	

Based on this score, the material validator stated that the interactive learning website using the Green Education model was good and worthy of being trialed in schools.

c. Teacher Assessment, regarding the interactive learning website using the Green Education model before the product was trialed with students, the teacher assessment results in the table above obtained a total score of 63 with an average of 4.5, within the range of >4.2-5.0, in the "Very Appropriate" category. Based on this score, the teacher assessment stated that the interactive learning website using the Green Education model was good and suitable for trial with students in the classroom.

### Implementation Stage

Next, in the implementation stage, interactive multimedia that has been deemed appropriate by experts and has been assessed by educators is first tested with one-on-one trials to obtain information on intrinsic aspects such as clarity, ease of use of the product, order of use and

also the completeness of elements in the product, then after obtaining this information, it is continued with small group trials.

After the students used the interactive multimedia, the researcher gave them the opportunity to discuss and ask questions about the Green Chemistry material. They were then asked to complete a distributed response questionnaire. The following are the results of a small group trial of 10 class X students at SMA 1 Gunung Meriah:

**Table 6.** Small group trial results

No.	Score										Total
	1	2	3	4	5	6	7	8	9	10	
1.	4	4	4	4	4	4	5	5	5	5	44
2.	4	4	4	4	4	4	4	4	4	4	40
3.	5	5	4	4	5	4	4	5	5	4	45
4.	4	4	4	5	5	4	5	5	5	4	45
5.	4	4	4	4	5	4	5	4	5	5	44
6.	5	4	5	4	4	4	4	5	4	5	44
7.	4	4	4	4	4	4	5	5	5	4	43
8.	5	4	5	4	4	4	4	4	4	4	42
9.	5	5	5	5	4	4	5	5	5	4	47
10.	4	4	4	4	4	4	4	4	4	4	40
11.	4	4	5	5	4	4	5	5	5	4	45
12.	4	4	5	4	5	4	5	4	4	4	43
13.	4	4	5	4	5	4	5	4	5	4	44
	Total										566
	%										87.07%
	Category										Very worthy

Based on the data above, the percentage of all students' answers was 87.07%, which is in the 81%-100% range, which is in the "Very Appropriate" category. Therefore, the researcher can conclude that the teaching materials that have been developed are very interesting and very good in supporting Green Chemistry learning and are practically feasible.

### Evaluation Stage

The evaluation stage is a process to review whether the product being developed is in accordance with initial expectations or not. Evaluation is carried out for the need for improvement in order to obtain a feasible product. Based on the validation results that have been carried out by material experts and media experts, the results show that the product being developed is good and suitable for testing in schools. The results of the questionnaire data for the assessment instrument and responses of chemistry educators from SMAN 1 Gunung Meriah, it was found that the developed teaching material product was good. Then from the questionnaire data for the student response instrument after using the interactive learning website that was tested, it was found that most students liked and were interested in the interactive learning website by giving a very decent response percentage of 87.07%. The attractiveness and suitability of the interactive learning website with the learning material presented were able to make students interested in learning Green Chemistry material and could increase student learning motivation.

Based on the results of the questionnaire data on student needs and characteristics distributed to 34 class X students of SMAN 1 Gunung Meriah, it shows that 70.6% of students find it difficult to learn and understand Green Chemistry material. The obstacle that makes it difficult for students to understand Green Chemistry material is the lack of availability of interesting learning media where 73.5% of students prefer digital teaching materials (PPT, learning videos, learning websites, android applications) compared to printed teaching materials (textbooks and LKS). Data also shows that 91.2% of students prefer chemistry learning that is applied directly. So 91.2% of students strongly agree with the application of the Green Education learning model in Green Chemistry material.

Based on the data from the needs analysis that has been carried out, it can be concluded that class X students of SMAN 1 Gunung Meriah need supporting media that can attract attention in learning so that students can easily understand Green Chemistry material. A Green Education learning model is also needed so that students are able to apply the Green Chemistry concept related to everyday life into something of economic value to help students understand the Green Chemistry concept. So with the supporting media that can attract attention in learning, students can easily understand Green Chemistry material independently and the learning process becomes more meaningful.

*A website is a learning tool that uses the internet network and provides all forms of information so that learning can be done not only face to face and is limited by time* (Pratama, 2021). Learning using websites is expected to be more enjoyable, as activities take place not only in the classroom but also in virtual classrooms. Teachers can use websites to convey difficult material. Website learning media can be displayed in the form of text, images, video, audio, moving animations, or a combination of all of these, interconnected and connected by a network of pages or hyperlinks (Rini et al., 2025). Students, as the objects of learning, must be equipped with a variety of skills and insights. The various types of knowledge gained during the learning process are expected to integrate with each other, thus providing benefits when they graduate. One learning innovation is the contextual Green Education approach. Green Education emphasizes the integration of environmental sustainability, resource conservation, and eco-literacy principles into the learning process. The goal is to develop students with the knowledge, attitudes, and skills to behave in an environmentally friendly manner in everyday life and in academic contexts (Khoerunisa, 2024).

This research is in line with several studies conducted by Sitompul et al., (2025b), Green education has a significant influence on students' science process skills. There is a significant influence between the Wordwall web media and student learning outcomes in thermochemistry material at Kosgoro Tomohon High School (Assa & Gugule, 2025). Student motivation towards using website media in learning acid and base material, overall obtained 86.7%, including the very good category (Dalimunthe et al., 2024). By integrating the principles of Green Chemistry into education, chemistry learning is expected to not only produce students who understand scientific concepts, but also have ecological awareness and the ability to apply chemistry sustainably (Simangunsong & Darmana, 2025).

The results of the development of an interactive learning website through the Green Education model on green chemistry material at SMAN 1 Gunung Meriah using the Lee & Owens development model, starting from the analysis, design, development, implementation, and evaluation stages have been tested in class X of SMAN 1 Gunung Meriah. The presentation of the material contained in the interactive learning website is able to attract motivation and help students in learning green chemistry material and can be used as a supporting medium for student learning both at school and independently at home.

## CONCLUSION

Based on the results of the research on the development of an interactive learning website through the Green Education model on Green Chemistry material, it can be concluded that the interactive learning website through the Green Education model on Green Chemistry material developed obtained a conceptually "Very Feasible" result based on the assessment of validation from media experts and material experts. So it can be stated that the developed interactive learning website is worthy to be tested as a learning medium in chemistry learning. The interactive learning website through the Green Education model on Green Chemistry material developed obtained a procedurally "Very Feasible" result based on teacher assessments and student responses to the developed product. So it can be stated that the developed interactive learning website is worthy to be used as a learning medium in chemistry learning. Further research is recommended using long-

term effect measurements, usability, and cost-effectiveness analysis to ensure this media is feasible for widespread implementation.

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