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Development of a Green Chemistry E-Module Integrated with Ethno-STEAM for Enhancing Senior High School Students' Environmental Conservation Skills

Epinur[1*], Fuldiaratman[1], Nelyahardi[2], Hendra[3], Minarni[1]

[1] Chemistry Education Study Program, Faculty of Teacher Training and Education, Universitas Jambi, Jambi, Indonesia.
[2] Guidance and Counseling Study Program, Faculty of Teacher Training and Education, Universitas Jambi, Jambi, Indonesia.
[3] Pancasila and Civic Education Study Program, Faculty of Teacher Training and Education, Universitas Jambi, Jambi, Indonesia.

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Corresponding Author:
Epinur
epinur63@unja.ac.id

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Abstract: This study developed and validated an Ethno-STEAM integrated e-module to enhance students' conservation skills using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). Data were collected through observations, interviews, and questionnaires. Expert validation results showed average scores of 4.6 for content, 4.875 for design, and 4.5 for practitioners, categorized as "very good" (interval 4.21–5.00). These findings confirm the feasibility of the e-module in terms of content quality, presentation, language, and design without significant revisions. Implementation results demonstrated notable improvements in students' science literacy. Prior to the intervention, students were distributed at level 1 (23.40%), level 2 (50%), and level 3 (26.60%), with no students reaching levels 4 or 5. After implementation, the distribution shifted to level 1 (7.40%), level 2 (10%), level 3 (40%), level 4 (36.70%), and level 5 (5.90%). The novelty of this research lies in integrating Ethno-STEAM with local wisdom, which not only improves science literacy but also fosters conservation values such as appreciation, pride, and care for local culture. The e-module is therefore recommended as an effective, scientific, and character-oriented medium for chemistry learning.

Keywords: Conservative skills; E-Module; Etno-STEAM

Introduction

It is undeniable that in the 21st century, globalization has shifted Indonesia's local cultural values. Indonesian culture is increasingly eroded by foreign cultures (Oxtariani et al., 2022). Therefore, local culture needs to be incorporated into the learning process. The integration of local culture can be initiated through the selection of teaching media that contain cultural values. The appropriate selection of teaching media in the learning process will provide a positive impact on students. Teaching media should be designed by considering several aspects such as students' needs, the characteristics of the material, and other factors that support its effectiveness (Sudjana & Rivai, 2007). Teachers are expected to develop interactive and engaging teaching materials to make the learning process more enjoyable and meaningful. With the use of learning materials that keep up with technological advancements, including artificial intelligence, learning will become more effective and the content delivered by teachers will be more easily understood by students (Sudarmin & Asyhar, 2012).

Chemistry is one of the exact sciences, often perceived as difficult by students. Thus, a learning approach is required that enables students to explore phenomena in their environment, incorporating local culture and wisdom into school chemistry lessons (Asriningrum et al., 2013). This culture-based chemistry learning is carried out through the reconstruction of

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indigenous scientific knowledge into chemistry concepts taught in schools (Sudarmin et al., 2020). The exploration of local culture is crucial for understanding indigenous knowledge integrated into schools. Traditional knowledge can foster ways of thinking, creativity, and cultural dynamics in a given region (Utari et al., 2021; Wahyudiati & Fitriani, 2021). The relevance of learning in daily life can be enhanced by utilising knowledge from the environment, including cultural elements, to provide students with authentic and meaningful experiences. Local phenomena can serve as a medium for more original and natural learning activities (Handayani et al., 2018). The interaction between students and their environment, through observation and comprehension, helps shape knowledge. This presents a challenge for teachers to introduce and integrate local culture into the learning process effectively. Such integration can be achieved by developing teaching media, such as e-modules. The STEM approach promotes the development of 21st-century skills (Stehle & Peters-Burton, 2019; Widya et al., 2019; Aisa et al., 2025). This study aims to develop a green chemistry e-module integrated with Ethno-STEAM to improve students' conservation abilities.

Ethno-STEAM is a learning approach that incorporates local culture into the teaching materials, viewed through five aspects: science, technology, engineering, art, and mathematics. Scientific knowledge within society is reconstructed into school chemistry learning (Rahayu & Sudarmin, 2015). The developed module is also equipped with images and videos to strengthen the cultivation of conservation character in students. The declining awareness of environmental responsibility is evident in schools: students neglect classroom duties, fail to care for plants, litter indiscriminately, and more.

The teaching module is structured in a well-organised manner, both explicitly and implicitly, to create an enjoyable classroom atmosphere that engages students in learning (Stit & Nusantara, 2020; Murtalib, 2022; Sunedi & Syaflin, 2024). There are also digital learning media that support this, namely e-modules. E-modules are self-learning materials that provide information in a digital format, making them easily accessible to users (Anggreni & Sari, 2022; Cynthia et al., 2023; Yersi et al., 2025). E-modules that combine text, images, animations, videos, and interactive simulations enable students to learn independently and according to their individual learning styles (Afifah et al., 2025; Sudirman et al., 2025). Digital learning media are flexible tools that allow students to access learning resources without being bound by specific learning hours (Hafizah, 2020; Purwita & Zuhdi, 2023; Yuninnur & Mukhlishin, 2025). This is due to the interesting visualization in the e-module, which can help students understand the material more easily (Adawiyah et al., 2021; Enawaty, 2023; Uz et al., 2019; Zahroni & Nurjayadi, 2025).

Therefore, concrete measures are required to address these issues. The learning system in schools tends to emphasize the quantity of results, not the quality of the process (Anugrasari, 2025). One effort is to integrate conservation character education into senior high school chemistry learning, for instance through Ethno-STEAM integrated e-modules.

The problems found in SMAN 13 Jambi City include limited Ethno-STEAM integrated teaching materials. Teaching materials that incorporate local culture remain scarce, so many teachers have not used them. Moreover, knowledge regarding the development of Ethno-STEAM integrated e-modules is limited, and many students are still unfamiliar with the local culture around them.

Learning integrated with culture provides students with more meaningful learning experiences. For example, ethnochemistry, which integrates chemistry with cultural contexts (Lestari et al., 2021). Through such integration, students are expected to identify local culture connected with chemistry concepts taught at school while simultaneously improving their conservation skills. In its application, science literacy enables students to think critically, analytically, and logically (Pratama, 2025).

Character education integrated into learning can provide meaningful experiences for students as they understand, internalize, and actualize values through the learning process. These values can be naturally absorbed through daily activities. When reinforced by school practices, character education becomes more effective (Zuchdi, 2010). Strengthening conservation skills in learning occurs through interaction. Such interactions between teachers and students can be enhanced by using engaging teaching materials. Interactive e-modules tailored to students' needs are expected to make learning more meaningful, even for concepts that are considered difficult (Parmin, 2017; Rahayu & Sudarmin, 2015).

Previous studies have widely examined the integration of local culture into learning. This is essential considering Indonesia's richness in cultural heritage. Many Indonesian cultures, such as batik, tenun, songket, and lippa sabe, have been recognized by UNESCO (Asna et al., 2024; Izzah et al., 2020). Therefore, it is important to embed culture within the learning process.

In this study, the researcher will develop an Ethno-STEAM integrated green chemistry e-module to enhance students' conservative abilities. The local culture incorporated in the e-module is ecoprint production using natural dyes from Jambi. The ecoprint-

making process involves aspects of science, technology, art, engineering, and mathematics.

The purpose of this study is to develop an Ethno-STEAM integrated e-module to improve students' conservative abilities, to examine the development process of such modules in addressing conservative skills, and to evaluate their validity and practicality based on expert and user assessments.

Method

The development model used in this study was the ADDIE model, which consists of several stages: Analysis, Design, Development, Implementation, and Evaluation. The stages of developing an Ethno-STEAM integrated e-module to improve students' conservation skills, the validity of the Ethno-STEAM integrated e-module in enhancing students' conservation skills, and teachers' assessments and students' responses regarding the practicality of the Ethno-STEAM integrated e-module were examined. After the media was developed, the research proceeded with an experimental test to determine the effectiveness of the product in improving learning outcomes on green chemistry material. The subjects of this study were tenth-grade students at SMAN 13 Jambi, Jambi Province. Quantitative data were converted into qualitative data. The guidelines for converting quantitative data into qualitative data are as follows:

$$\ddot{X}\imath = \sum_{n} X \quad (1)$$

Explanation:
$\ddot{X}\,i$ = Average score
ΣX = Total Score
N = Number of Respondents

The conversion of quantitative data into qualitative data was carried out using the following guidelines a) The developed product is categorized as Very Good (VG) if the average score obtained is between 4.21 – 5.00. b) The developed product is categorized as Good (G) if the average score obtained is between 3.41 – 4.20. c) The developed product is categorized as Fair (F) if the average score obtained is between 2.61 – 3.40. d) The developed product is categorized as Poor (P) if the average score obtained is between 1.81 – 2.60. e) The developed product is categorized as Very Poor (VP) if the average score obtained is between 1.00 – 1.80.

The stages of developing an Ethno-STEAM integrated e-module to improve students' conservative skills, the validity of the Ethno-STEAM integrated e-module in enhancing students' conservative skills, and teachers' assessments and students' responses regarding the practicality of the Ethno-STEAM integrated e-module.

Results and Discussion

The results obtained from this research and development include the stages of developing an Ethno-STEAM integrated e-module to improve students' conservation skills, the validity of the Ethno-STEAM integrated e-module in enhancing students' conservation skills, and teachers' assessments and students' responses regarding the practicality of the Ethno-STEAM integrated e-module. The steps in developing the e-module were carried out using the ADDIE development model (Analysis–Design–Development–Implementation–Evaluation). In this study, the researcher only conducted the process up to the small-group evaluation stage. The stages of ADDIE are as follows:

Analysis Stage

At this stage, the researcher conducted a needs analysis, subject matter analysis, and student characteristics analysis to identify students' needs. An unstructured interview was conducted during the preliminary observation to determine the opinions of subject teachers regarding the e-module to be developed (Ramadani et al., 2023). Several questions were asked related to teaching materials, curriculum, local wisdom-based learning, assignments, and students' scientific literacy skills.

It was found that the teaching materials used by teachers consisted of textbooks, practice questions, and tests, which had not yet incorporated literacy-based texts. Meanwhile, the analysis of student characteristics aimed to obtain information about students' prior knowledge of the material, interests, motivation, learning styles, and their responses to the learning process. At this stage, the researcher also asked students about their opinions on the use of teaching materials other than textbooks, such as modules or other supporting media.

The research was conducted at SMAN 13, Jambi City. One of the new topics in Grade X Chemistry under the Merdeka Curriculum is Chemistry in Our Daily Life, which includes the subtopic Green Chemistry. This subtopic covers the principles of green chemistry and issues of global warming. As a conceptual subject, it requires appropriate strategies, models, and teaching materials that meet students' needs and create effective learning processes by presenting contextual and meaningful projects. Teachers therefore need to apply real-life phenomena in delivering the material, since the

lack of contextual approaches has contributed to low scientific literacy skills among students.

The forms of questions provided by teachers also did not reflect literacy-based problem types. Typically, questions were presented directly without contextual texts or phenomena. As a result, students' literacy skills remained low because they were not accustomed to reading-based problems. Moreover, teachers rarely engaged students in laboratory experiments, which also contributed to students' low conservation character.

Furthermore, a literature review was conducted on several relevant studies (Herlina et al., 2022). The review revealed that certain medicinal plants are commonly used by the Suku Anak Dalam (SAD) and communities in Tebo. By applying the STEAM approach, students are expected to acquire various skills necessary to meet the challenges of the 21st century, including scientific literacy (Risamasu et al., 2023).

Design Stage

At the design stage, the researcher created a new and engaging framework to improve the learning program (Prawiradilaga, 2014). The initial design of the e-module content began with the learning material, the implemented curriculum, and the characteristics of students in the learning process. The first step taken was to determine the e-module development team, resources, development schedule, scope of learning, sequence of subject matter, rough design, and product specifications in the form of an e-module.

The research instrument validators consisted of media experts and material experts, as well as practitioner validators including teachers and students as users of the e-module to be developed. The preparation of the development schedule aimed to ensure that all stages would be carried out systematically during the e-module development process. The scope, structure, and sequence of the material were outlined in the form of learning outcomes (LO), objectives, learning achievement criteria (LAC), Pancasila student profile, guidelines, concept maps, teaching materials, student activities during the learning process, and exercises. The e-module was developed using Canva. The storyboard design included learning outcomes (LO), objectives, learning achievement criteria (LAC), Pancasila student profile, guidelines, concept maps, teaching materials, student activities during the learning process, and practice questions developed in the e-module.

Development Stage

The development stage was carried out with the aim of validating the developed learning tools. The validation consisted of expert validation, namely by a material expert and a design expert.

The material validation was conducted by the material expert, Mrs. Minarni, S.Pd., M.Si. After reviewing and reading the green chemistry e-module integrated with Ethno-STEAM, designed to improve conservation skills, the material expert provided an assessment of the content in the green chemistry e-module integrated with Ethno-STEAM. After the learning tool was revised based on comments and suggestions, it was shown again to the material expert to review the revisions made. The material validation by the expert was conducted twice. The following are the comments and suggestions given during the validation of the green chemistry e-module integrated with Ethno-STEAM. Based on the results of the material expert validation, an average score of 4.6 was obtained, which falls within the range of 4.21 – 5.00. This range is included in the "very good" (VG) category. Thus, the developed e-module product can be declared to have a very high level of feasibility. These results indicate that the e-module developed has met the feasibility standards in terms of content, presentation, and language aspects, and is considered capable of supporting the learning process according to students' needs. An assessment in the "very good" category shows that the developed product is not only feasible for use but also of high quality, making it potentially able to provide a positive impact on improving the quality of learning. Therefore, it can be concluded that the developed e-module in this study is categorized as very good (VG), so it is feasible to use and recommended for implementation in learning activities. Previous studies have shown that the development of digital teaching materials, particularly those designed with visual and interactive elements, can improve students' conceptual understanding and motivation to learn (Minarni et al., 2019).

The second expert validation carried out was the design validation by the design expert, Mr. Drs. Fuldiaratman, M.Pd. After reviewing and reading the developed learning tools, the design expert provided an assessment related to the e-module design through questionnaires, as well as comments and suggestions on the integrated green chemistry Ethno-STEAM e-module. After the learning tools were revised according to the comments and suggestions, the revised version was shown again to the design expert for further review. The design validation by the design expert was conducted twice. The following are the comments and suggestions provided during the validation of the design of the integrated green chemistry Ethno-STEAM e-module.

Based on the results of the design expert validation, the average score obtained was within the range of 4.21–5.00. Thus, the average score of 4.875 obtained in this study falls into the very good category. This result indicates that the developed product has met very high-

quality standards. All aspects assessed through the evaluation instrument received highly positive appreciation from the respondents. In other words, the developed product not only meets the needs but is also considered effective, practical, and feasible for use in a learning context.

The feasibility with a "very good" category shows that respondents judged the product as successfully achieving the development objectives, both in terms of content substance, appearance, clarity, and its usefulness for users. This strengthens the argument that the product does not require major revisions and can be more widely implemented in learning practices.

Implementation and Evaluation Stage

The implementation stage included formative evaluation in the form of one-to-one evaluation and group evaluation. The one-to-one evaluation was conducted to obtain initial feedback on the developed product from one Chemistry teacher who was experienced and competent in the field. After reviewing and reading the green chemistry e-module integrated with Ethno-STEAM, which was designed to improve conservation skills, the teacher was then asked to provide an assessment of the learning tool using a questionnaire as well as comments and suggestions in the revision column provided.

Based on the evaluation given by the practitioner on the developed product, a total score of 90 was obtained from 20 statement items. The average score was calculated at 4.5. This average score falls within the interval of $4.21 \leq 5.00$, categorized as very good (VG). The practitioner's assessment in the very good category also indicates that the product is feasible to be used in learning practices without requiring significant revisions.

The group evaluation was carried out by asking for feedback from 30 students of Class X by presenting the green chemistry e-module integrated with Ethno-STEAM, designed to improve conservation skills. Afterwards, the 30 students of Class X SMAN 13 Kota Jambi were asked to complete the provided questionnaire. The results of the students' responses in the group evaluation of the learning tool were as follows:

After the implementation of the green chemistry e-module integrated with Ethno-STEAM, designed to improve conservation skills, an increase in students' science literacy levels was observed, level 1: 7.4% (previously 23.4%), level 2: 10% (previously 50%), level 3: 40% (previously 26.6%), level 4: 36.7% (previously 0%), level 5: 5.9% (previously 0%).

These results show that students' science literacy improved significantly. Science literacy develops continuously and should be assessed periodically. One survey to measure students' science literacy skills is the PISA test, conducted every three years. Science literacy instruments must be developed to measure students' ability to apply scientific concepts in daily life. The importance of science literacy instruments lies in their ability to train students' scientific thinking skills. Multiple-choice questions can be used to identify students' level of science literacy (Novanti et al., 2018).

Ethno-STEAM plays an important role in developing science literacy through the contextualization of scientific concepts with local culture. Through this strategy, students not only understand science in an abstract way but also connect it with daily practices passed down from generation to generation. At the same time, this approach strengthens students' conservation skills by instilling pride, appreciation, and respect for local traditions. Thus, the integration of Ethno-STEAM, science literacy, and conservation fosters students who are scientific, cultured, and able to maintain their identity in the era of globalization. Digital learning using STEM-based e-modules has a positive impact on students' critical thinking skills (Mulyasari & Sholikhah, 2021; Kurnia & Gita, 2025). E-Modules designed with a STEM approach can improve students' learning independence (Inanna et al., 2021; Lastri, 2023; Sikumbang et al., 2025).

Conclusion

The learning materials were developed using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). The research findings showed that the green chemistry e-module integrated with Ethno-STEAM was categorized as very good (VG) based on the validation results from material experts (average scores of 4.6 and 4.875), design experts, and practitioner testing (average score of 4.5). The product was declared feasible for use as it met the standards of content, presentation, language, and attractive design without requiring significant revisions. The integration of Ethno-STEAM not only enhanced students' science literacy but also fostered conservation-oriented competencies, such as appreciation, pride, and care for local culture. Therefore, this e-module is recommended for implementation in chemistry learning as an effective, scientific, and character-building medium.

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Author Contributions

Conceptualization, Epinur and Fuldiaratman; Methodology, Epinur, Fuldiaratman, and Minarni; Investigation, Epinur, Fuldiaratman, and Minarni; Formal Analysis, Epinur and Nelyahardi; Resources, Epinur, Fuldiaratman, Minarni, and Hendra; Data Curation, Nelyahardi and Hendra; Writing—Original Draft, Epinur; Writing—Review & Editing, Fuldiaratman, Minarni, and Nelyahardi; Supervision, Fuldiaratman; Project Administration, Epinur; Funding Acquisition, Epinur and Fuldiaratman. All authors have read and approved the final manuscript.

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Conflicts of Interest

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