



STEAM-Integrated Hydrocarbon E-Module: A Digital Learning Innovation for Environmental Literacy

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Abstract: This study aims to develop an integrated hydrocarbon e-module based on the STEAM approach to support students' environmental literacy. The study employed a Research and Development (R&D) methodology using the ADDIE model, limited to the analysis, design, and development stages. The research was conducted at a public senior high school in Central Java, Indonesia. The research instruments included an expert validation sheet, a readability questionnaire, and teacher and student response questionnaires. The data were analyzed descriptively by calculating the percentage of the obtained scores relative to the maximum possible scores and interpreting the results based on predetermined criteria. The developed e-module consists of interactive digital instructional materials presented in a Heyzine-based flipbook format that integrates the STEAM approach and environmental issues into hydrocarbon topics. The expert validation results yielded a score of 95.15%, categorized as "highly valid," while the readability test yielded a score of 89%, categorized as "very good." These results indicate that the developed e-module is suitable as an alternative digital teaching material for supporting more contextualized hydrocarbon learning and fostering students' environmental literacy.

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Introduction

Environmental degradation is an increasingly complex global challenge with far-reaching implications for the sustainability of human life. Climate change, air pollution, the accumulation of plastic waste, and the decline in the quality of natural resources are largely driven by human activities that have not yet taken sustainability principles into account (Pratiwi *et al.*, 2022; Santoso, 2021). These conditions indicate that solving environmental problems does not depend solely on government policies but also requires changes in the public's knowledge, attitudes, and behaviors toward the environment (Hartanti & Wardhana, 2023). One strategic effort to foster this awareness is through education that equips students with the competencies to understand, analyze, and make decisions regarding various environmental issues (Hariyadi *et al.*, 2021).

Education plays a crucial role in shaping a generation with environmental literacy. Environmental literacy is not only about mastering knowledge but also encompasses the thinking skills, attitudes, and behaviors that support environmental conservation (Ardoin *et al.*, 2022). Integrating environmental literacy into the learning process is expected to foster students' awareness of various environmental issues from an early age so that they can participate in efforts to address them (Spínola, 2021). Therefore, science education, particularly chemistry, needs to be designed contextually so that students can connect scientific concepts to environmental phenomena occurring around them.



One topic in chemistry that is closely related to environmental issues is hydrocarbons. This topic covers the compounds that make up fossil fuels, crude oil, natural gas, and various derivative products such as plastics whose use is deeply embedded in our daily lives. On the other hand, the combustion of hydrocarbons produces greenhouse gas emissions, while hydrocarbon-based waste contributes to environmental pollution. This connection makes the topic of hydrocarbons highly suitable as a learning context for developing students' environmental literacy through the analysis of real-world environmental problems (Zandroto & Sinaga, 2022).

Chemistry instruction in schools still faces various challenges. Based on interviews with 12th-grade chemistry teachers at high schools in Semarang, instruction is still dominated by the use of textbooks, PDF-format teaching materials, and simple presentation tools. The presentation of material has not been able to effectively visualize abstract concepts or connect them to real-life environmental issues. As a result, students tend to memorize concepts without understanding how to apply them to solve environmental problems (Eliza *et al.*, 2021). This situation highlights the need to develop instructional media capable of presenting material in a more interactive, contextual, and student-centred manner.

Advances in information technology provide opportunities to develop more innovative learning materials through the use of electronic modules (e-modules). E-modules allow for the presentation of material in the form of text, images, videos, animations, and interactive assessments, thereby enabling the visualization of abstract chemical concepts while supporting self-directed learning (Hazrullah & Lubis, 2023; Hidayati Azkiya *et al.*, 2022). To ensure that learning is not solely focused on mastering concepts, e-modules need to be integrated with an approach that connects scientific concepts to real-world problem-solving. One relevant approach is STEAM (Science, Technology, Engineering, Arts, and Mathematics), as it encourages students to integrate various disciplines in analyzing problems, thinking creatively, and generating solutions to environmental issues.

Various studies have shown that the development of electronic teaching materials can improve the quality of chemistry learning. Based on, Fitri & Iryani, (2023) and Zhafirah *et al.*, (2020) developed Problem-Based Learning (PBL)-based e-modules that were found to have a high level of validity and to facilitate self-directed learning through interactive presentation of material. Research by (Safitri & Sari, 2022) indicates that STEAM-based e-modules covering the topics of salt hydrolysis as well as electrolyte and nonelectrolyte solutions exhibit excellent levels of validity and practicality. Meanwhile, (Fikrina *et al.*, 2023) developed an ethno-STEAM-based e-module capable of enhancing students' creative thinking skills, while Kusnadi *et al.*, (2023) and Saragih & Tanjung, (2023) demonstrated that both STEAM and STEM-based learning tools are effective in improving students' environmental literacy.

Nevertheless, these studies still leave some gaps. Most studies on the development of STEAM-based e-modules focus only on testing the validity and practicality of the products, while research on their effectiveness in improving environmental literacy remains limited. Furthermore, STEAM has been implemented primarily in topics such as reaction rates, salt hydrolysis, and electrolyte and nonelectrolyte solutions, while its application to hydrocarbons remains relatively limited. Research on environmental literacy also generally employs learning tools such as modules, worksheets, or project-based learning materials; consequently, the use of interactive e-modules as a medium to enhance environmental literacy in hydrocarbon-related topics has not yet been extensively studied.



Based on this background, this study offers a novel approach in the form of an e-module on hydrocarbons that integrates the STEAM approach to enhance students' environmental literacy. The e-module was designed not only as interactive digital teaching material but also to link hydrocarbon concepts to various environmental issues, thereby making learning more contextual. In addition to the development of the e-module, this study focuses on evaluating the validity and readability of the product. The validity assessment involves expert evaluation of the content, presentation, and language, while the readability assessment examines students' perceptions of the clarity and comprehensibility of the e-module. Therefore, this study is limited to the product development, expert validation, and feasibility/readability testing stages and does not evaluate the effectiveness of the e-module in improving students' environmental literacy.

Research Method

This study is a research and development (R&D) project aimed at producing an integrated Science, Technology, Engineering, Arts, and Mathematics (STEAM) electronic module (e-module) on hydrocarbons to improve students' environmental literacy. The development model used is the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation). However, the study was limited to the Development stage because its objective was focused on determining the characteristics, feasibility, and practicality of the developed e-module.

The research was conducted through the three stages of the ADDIE model is Analysis, Design, and Development. The Analysis stage included a needs analysis, an analysis of student characteristics, a curriculum analysis, and an analysis of hydrocarbon material. The needs analysis was conducted through classroom observations, interviews with chemistry teachers from several high schools in Semarang, and a literature review on chemistry education and the development of digital learning media. The analysis of learner characteristics was conducted using a learner needs questionnaire to identify learning characteristics, learning interests, learning difficulties, and the availability of digital devices that support the use of the E-Module. Meanwhile, the analysis of the curriculum and content was carried out by reviewing learning outcomes, learning objectives, and hydrocarbon content in accordance with the applicable curriculum.

The Design phase includes designing the structure of the E-Module, selecting learning materials and media, developing STEAM-based learning activities, integrating environmental issues into the context, and developing research instruments. Next, during the Development phase, product development, expert validation, product revisions, readability testing, and practicality testing were conducted. The resulting product is an E-Module on hydrocarbons in the form of a digital flipbook that can be accessed via the Heyzine platform.

The participants involved in this study consisted of two groups with different roles. A Grade 11 chemistry teacher participated in the needs analysis to provide information regarding students' learning needs, the challenges encountered in teaching hydrocarbon concepts, the use of existing learning resources and part of expert validators. Grade 12 students from Semarang State High School 7 participated in the product readability test. Grade 12 students were selected because they had previously studied hydrocarbon concepts, enabling them to assess the clarity, comprehensibility, and usability of the developed e-module based on their prior learning experience.

The expert validators consisted of two chemistry education lecturers from UNNES and one chemistry teacher from Semarang State High School 7, who were tasked with



assessing the suitability of the research product and instruments. The students were involved in testing the readability and practicality of the E-Module. Quantitative data collection in this study was conducted using expert validation sheets, readability questionnaires, and student response questionnaires. The research instruments were designed using a Likert scale to determine the respondents' evaluations, perceptions, and responses to the developed E-Module. The variables being measured were first broken down into several indicators, which were then developed into specific statements within the research instruments.

In this study, respondents' assessments were measured using a Likert scale. This scale was used to determine respondents' reactions, perceptions, and attitudes toward the statements presented through several response categories ranging from the most positive to the most negative. The assessment results were obtained by summing the scores for each respondent's answers (Priatna *et al.*, 2024). The research instrument used a four-point scale with positive rating categories, as shown in Table 1.

Table 1. Likert Scale Scoring Criteria

Category	Score
Strongly Agree	4
Agree	3
Disagree	2
Strongly Disagree	1

The criteria for assessing expert validity in this study are presented in Table 2.

Table 2. Questionnaire Validator Scoring Criteria

Validator Score	Category
$15 \leq x \leq 26,25$	Highly Invalid
$27 \leq x \leq 37,5$	Invalid
$38 \leq x \leq 48,75$	Valid
$49 \leq x \leq 60$	Highly valid

Results and Discussion

The research results presented cover the e-module development process during the Analysis, Design, and Development stages, including needs analysis, product design, characteristics of the developed e-module, expert validation results, product revisions, and usability test results. Each stage is discussed systematically to demonstrate the quality of the resulting product as a digital teaching resource on hydrocarbons.

Analysis

The analysis phase was conducted to identify the needs for e-module development through curriculum analysis, analysis of student characteristics, content analysis, and learning needs analysis. Results from interviews with chemistry teachers from several high schools in Semarang, as well as a literature review, indicate that the learning process is still dominated by the use of textbooks and worksheets as the primary learning resources. The use of technology in chemistry instruction remains limited, so the media currently used are unable to visualize abstract chemical concepts or connect them to environmental issues in everyday life. This situation makes learning less engaging and does not fully encourage students' active participation. An analysis of student characteristics also shows that the majority of students already own smartphones and are accustomed to using digital devices in their learning activities. The results of this analysis served as the basis for developing e-modules as a learning medium capable of integrating text, images, animations, videos, and interactive



quizzes, thereby supporting self-directed learning while enhancing students' environmental literacy skills.

Design

Based on the results of the needs analysis, the design phase focused on developing an e-module on hydrocarbons that integrates the STEAM approach. The design process included selecting media, determining the format, organizing the content, and designing the e-module interface. Electronic modules were chosen as the medium because they provide students with the flexibility to access the material anytime and anywhere according to their learning needs. The e-module is designed in A4 format with a portrait orientation so that content, illustrations, tables, and graphs can be displayed proportionally. The e-module's interface uses a simple color scheme with illustrations, icons, animations, and supporting characters to enhance visual appeal. Furthermore, the e-modules include links to instructional videos and additional learning resources, allowing students to have a more interactive learning experience. All components of the e-modules are structured to integrate elements of Science, Technology, Engineering, Arts, and Mathematics into every learning activity, with the aim of helping students understand hydrocarbon concepts while developing their environmental literacy skills.

Development

The development phase began with the creation of a preliminary draft of the e-module based on the results of the needs analysis and design developed in the previous phase. The preliminary draft was then reviewed with the supervising instructor to obtain feedback on the content, organizational structure, and visual presentation of the e-module. This feedback was used as the basis for refining the product before it was validated by experts. The e-module developed is characterized as a digital teaching resource that is systematically organized and integrated using the Science, Technology, Engineering, Arts, and Mathematics (STEAM) approach. The structure of the e-module consists of a cover page, preface, table of contents, user guide, learning objectives, indicators of learning objective achievement, concept map, learning activities, practice questions, evaluation, summary, self-assessment, answer key, glossary, bibliography, and author biography. All components are arranged sequentially to facilitate students' independent study of hydrocarbon material.

The main characteristic of the e-module is the integration of STEAM into hydrocarbon learning. The Science component connects hydrocarbon structures, properties, and reactivity with environmental phenomena, particularly pollution associated with fossil-fuel use. The Technology component introduces scientific information and environmentally oriented technologies, such as IoT-based biogas and emission converters, and invites students to consider their applications in addressing environmental problems. The Engineering component involves analyzing engineering applications and considering alternative solutions to environmental problems. The Arts component provides opportunities for students to communicate environmental information through posters or infographics and to visualize hydrocarbon structures. The Mathematics component is incorporated through activities involving hydrocarbon nomenclature, molecular structures, and structural representations.

In addition to integrating the STEAM approach, the e-modules were also developed to address various environmental issues that are contextual and relevant to students' daily lives, such as air pollution caused by the burning of fossil fuels, plastic waste management, and the environmental impact of styrofoam use. Presenting the material in relation to real-world problems is expected to help students understand the connection between hydrocarbon concepts and environmental issues while developing their environmental literacy skills.

E-modules are developed as interactive flipbooks using the Heyzine platform, making them accessible online via computers, tablets, or smartphones without the need to install any additional apps. The flipbook format allows for a more engaging presentation of material through the integration of text, images, animations, instructional videos, and links to supplementary learning resources. These features make the e-module more interactive, flexible, and capable of facilitating self-directed learning tailored to students' needs.



Figure 1. Overview of the developed hydrocarbon e-module



Figure 2. Integration of STEAM components in the developed e-module: (a) Science, (b) Technology, (c) Engineering, (d) Arts, and (e) Mathematics.

Feasibility Analysis of the STEAM-Integrated Hydrocarbon E-Module through Expert Validation and Readability Testing

The product developed in this study is a STEAM-Integrated Hydrocarbon E-Module designed to improve students' environmental literacy. The e-module is deemed feasible if it meets the feasibility criteria based on both expert validation and readability results from students in a pilot test. This is in line with research by Sulistiyan *et al.*, (2020), which states that feasibility testing is determined through assessments by expert validators and students in a pilot test. Validation of the e-module was conducted by two lecturers from the Chemistry Education Study Program at Semarang State University and one chemistry teacher from Semarang State High School 7. The results of the e-module validation by the validators can be seen in Table 3.

Table 3. E-Module Validation Results by Validators

No.	Validator	Score	Percentage	Criteria
1.	Validator 1	141	92,76%	Highly Valid
2.	Validator 2	151	99,34%	Highly Valid
3.	Validator 3	142	93,42%	Highly Valid
Total Score			434	
Average Percentage			95,15%	
Category			Highly Valid	

Based on the results in Table 3, the Integrated STEAM Hydrocarbon E-Module developed in this study received a validation score of 95.15% from three experts, placing it in the "highly valid" category with some revisions. Therefore, this E-Module is highly suitable for use on a broader scale. Revisions to the E-Module were made to improve the product and



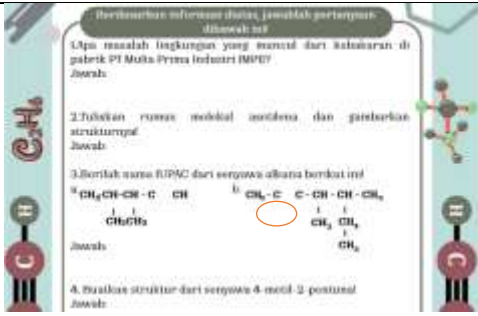
make it a better teaching resource. This is supported by research Ainy *et al.*, (2024), which reveals that before a product is used on a large scale, an assessment in the form of validation by experts namely, lecturers and teachers is necessary. The suggestions and feedback provided by the validators for improving the E-Module are presented in Table 4.

Table 4. Suggestions and Feedback from Validators

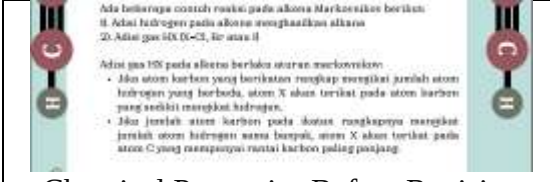
No	Validator	Suggestions for Improvement
1)	Validator 1	1. Some parts are difficult to read due to the dark background color. 2. Some words could be corrected, such as “di bawah” instead of “di bawah.”
2)	Validator 2	1. Improve the design of the E-Module content. 2. Some structural labels are still incorrect; please correct them.
3)	Validator 3	1. Add examples of reactions for physical and chemical properties. 2. Review the structural formulas again; some are still incorrect.

Based on feedback from the validators, the E-Module was revised with several adjustments as shown in the following table:

Table 5. Revisions Based on Suggestions and Feedback from Validators

Before Revision	After Revision
 E-Module Content Design Before Revision	 E-Module Content Design After Revision
 Structural Formulas Before Revision	 Structural Formulas After Revision



 Ada beberapa contoh reaksi pada alkana Markovnikov berikut: ii. Adisi hidrogen pada alkana menghasilkan alkana 2i. Adisi gas HX ($\text{H}-\text{X}$, H atau X) Adisi gas H_2 pada alkana berlaku aturan Markovnikov: • Jika atom karbon yang berikatan rangkap memiliki jumlah atom hidrogen yang berbeda, atom X akan terikat pada atom karbon yang sedikit memiliki hidrogen. • Jika jumlah atom karbon pada skema rangkapnya memiliki jumlah atom hidrogen sama banyak, atom X akan terikat pada atom C yang rangkapnya rami karbon paling panjang.	 ii. Adisi hidrogen pada alkana menghasilkan alkana $\text{C}_2\text{H}_4 + \text{H}_2 \rightarrow \text{C}_2\text{H}_6$ iii. Adisi gas HX pada alkana Adisi gas HX pada alkana mengikuti aturan Markovnikov: • Jika atom karbon yang berikatan rangkap memiliki jumlah atom hidrogen yang berbeda, atom X akan terikat pada atom karbon yang sedikit memiliki hidrogen. • Jika jumlah atom karbon pada skema rangkapnya memiliki jumlah atom hidrogen sama banyak, atom X akan terikat pada atom C yang rangkapnya rami karbon paling panjang.
Chemical Properties Before Revision	Chemical Properties After Revision

Revisions to the E-Module product were made to improve it as a teaching resource. The improvements made are detailed in Table 4.3. This is supported by research Hariani *et al.*, (2020), which reveals that before a product is used on a large scale, it must undergo validation by experts, namely university professors and teachers. The validation of the E-Module product consists of nine aspects: cover design, layout, images and illustrations, color, practicality, content suitability, presentation suitability, language, and STEAM learning activities.

After the integrated STEAM hydrocarbon e-module was validated by the validator, a small-scale pilot test was conducted to assess the product's readability before proceeding to the next phase of testing. The small-scale pilot test involved 20 students from Class XII IPA 1. This stage was crucial to ensure that the e-module was easy to understand, had an engaging design, and could be effectively used by students. Conducting a small-scale trial before product implementation is in line with research Zhafirah *et al.*, (2020), which states that preliminary trials are necessary to identify product shortcomings before it is applied to a broader learning context.

During the small-scale pilot test, students were asked to study the e-module, access all available features, and try out each learning component to ensure the e-module functioned properly. Next, students filled out a feedback questionnaire consisting of 15 statements covering the readability, ease of use, presentation of material, appearance, and usefulness of the e-module. In addition, students also provided suggestions and feedback to serve as evaluation material for refining the e-module before it was used in the practical testing phase.

Table 6. Readability Test Results for the Small-Scale Pilot E-Module

No.	Aspect	Score	Percentage	Criteria
1.	Ease of Understanding the Material and Environmental Issues	271	90%	Very Practical
2.	Interest and Engagement in Learning	263	88%	Very Practical
3.	Environment-Based and Critical Thinking Learning Activities	267	89%	Very Practical
4.	E-Module Design and Ease of Use	267	89%	Very Practical
Total Score			1068	
Average Percentage			89%	
Category			Very Practical	

The results of the readability survey show that the e-module received an average score of 53.4, representing 89%, which falls into the "very practical" category. These results indicate that the e-module has a high level of readability, allowing students to easily understand the content, usage instructions, and learning activities. The visual presentation, systematic organization, and use of communicative language also make it easier for students to study hydrocarbon material independently. The readability result provides additional support for the usability of this approach.



Discussion

The validation and readability result provides initial evidence that the developed e-module was accessible to students in terms of content presentation, instructions, and learning activities. This accessibility is important for a digital chemistry learning resource because hydrocarbon concepts involve symbolic representations, molecular structures, nomenclature, and chemical properties that require clear and consistent presentation. The validation process therefore played an important role in ensuring that these elements were scientifically accurate and appropriately organized (Safitri & Sari, 2022). Feedback concerning structural formulas, chemical properties, and content organization was not merely a technical correction but also contributed to the reliability of the learning resource as a chemistry teaching material.

The development of the e-module addresses the need for chemistry learning resources that can connect abstract hydrocarbon concepts with environmental issues relevant to students' everyday lives. This connection is theoretically important because meaningful learning occurs when students can relate new scientific concepts to familiar contexts and use them to interpret real world phenomena (Ardoin *et al.*, 2022). In hydrocarbon learning, concepts such as molecular structure, properties, reactions, and combustion can otherwise be learned primarily as symbolic or factual knowledge. Integrating these concepts with issues such as fossil-fuel combustion, plastic waste, and environmentally friendly technologies provides a context for students to interpret chemical concepts in relation to their environmental consequences. This contextual orientation is consistent with previous research showing that environmental and socioscientific contexts can help students connect scientific knowledge with real-life problems and develop more meaningful understanding.

The integration of PjBL and STEAM provides a pedagogical mechanism for translating this contextual content into active learning experiences (Nurhayati *et al.*, 2023). PjBL shifts students' learning activities from receiving information toward investigating problems, planning solutions, producing outputs, and communicating their ideas. STEAM complements this process by encouraging students to approach the same environmental problem through multiple forms of knowledge rather than treating chemistry as an isolated discipline. For example, students can use scientific knowledge to explain hydrocarbon-related phenomena, consider technological or engineering solutions, communicate ideas visually, and apply logical or mathematical reasoning. The combination therefore has the potential to support the integration of conceptual understanding with higher-order learning processes. This interpretation is in line with previous studies reporting that PjBL integrated with STEAM can provide contextual and student-centered learning experiences in chemistry (Fikrina *et al.*, 2023).

The environmental issues embedded in the e-module also provide a meaningful foundation for environmental literacy. Environmental literacy is not limited to knowing environmental facts, it involves understanding environmental problems, recognizing relationships between human activities and environmental consequences, and considering appropriate responses (Sulistiyanti *et al.*, 2020). The use of hydrocarbon-related environmental issues can provide opportunities for students to make these connections because hydrocarbons are closely related to energy use, combustion, plastics, and other environmental concerns. Thus, the contribution of the e-module is not simply the digitization of hydrocarbon teaching materials, but the integration of chemical knowledge with contexts through which students can interpret the environmental implications of chemistry. However, because this study was limited to the Analysis, Design, and Development stages and focused



on product validation and readability, these potential contributions should not be interpreted as evidence that the e-module has already improved students' environmental literacy.

Involving users in assessing instructional materials is also important because it provides direct insight into their ease of use, usefulness, and suitability for learning needs. This is consistent with Kusnadi *et al* (2023), who stated that the assessment of instructional materials should involve teachers and students as primary users. User responses can serve as an indicator of the suitability of instructional materials (Milala *et al.*, 2021). Validated response instruments can provide more accurate and reliable data for assessing practicality (Rosyada *et al.*, 2025). In the present study, the positive student responses suggest that the integration of environmental issues and STEAM-oriented activities remained accessible to learners. This is relevant because interdisciplinary content and multimedia elements may increase the cognitive demands of learning materials when they are not organized clearly. The systematic organization of the e-module may therefore have supported students' access to its content and activities. Nevertheless, these findings represent students' perceptions of clarity and usability and should not be interpreted as evidence of learning effectiveness.

The findings also have practical implications for chemistry teachers. The e-module can be used as a supplementary resource for designing contextual and student-centered hydrocarbon learning, particularly when teachers want to connect chemical concepts with environmental problems. Its digital format allows teachers to incorporate learning resources such as videos and external materials while providing a structured sequence of activities. At the same time, the e-module should function as a learning support rather than replace teacher facilitation. Teachers remain important in guiding students' interpretation of environmental issues, facilitating discussion, and connecting learning activities with the underlying chemistry concepts. Therefore, the developed e-module provides a model of how digital chemistry materials can integrate content knowledge, STEAM, project-based learning, and environmental contexts within a single learning resource. Further classroom implementation and effectiveness testing are needed to determine whether this integration can contribute to improvements in students' environmental literacy.

Conclusion

The resulting e-module is a digital teaching resource in the form of an interactive flipbook that integrates hydrocarbon concepts with environmental issues. Validation results show a validity rate of 95.15% (highly valid) and a readability score of 89% (highly practical). These results indicate that the e-module is suitable for use as an alternative digital teaching material to support hydrocarbon learning. For classroom practice, chemistry teachers can use the e-module to facilitate contextual and student-centered learning by connecting hydrocarbon concepts with environmental issues. Further research is needed to examine its effectiveness in improving students' environmental literacy through classroom implementation.

Recommendation

Based on the findings of this study, the following recommendations are proposed for educational practice and future research.

1) Practical/Policy Recommendations

The developed e-module can be considered by education authorities as an alternative digital teaching resource to support contextual and environmentally oriented chemistry



learning. Teachers can use the e-module as a supplementary resource to facilitate interactive and student centered learning on hydrocarbon topics.

2) Future Research Directions

Further research is recommended to continue development through the Implementation and Evaluation phases to test the e-module's effectiveness in improving students environmental literacy on a broader scale. Future researchers may also involve larger samples and different school contexts to examine the applicability of the e-module.

References

- Ainy, H. Q., Supeno, & Ahmad, N. (2024). Pengembangan E-Modul Berbantuan Flipbook Digital Untuk Meningkatkan Kemampuan Problem Solving Siswa Smp Pada Pembelajaran Ipa. *Jurnal Ilmiah Pendidikan Citra Bakti*, 11(1), 102–115. <https://doi.org/10.38048/jipcb.v11i1.3090>
- Ardoyn, N. M., Bowers, A. W., & Wheaton, M. (2022). Leveraging collective action and environmental literacy to address complex sustainability challenges. *Ambio*, 52(1), 30–44. <https://doi.org/10.1007/s13280-022-01764-6>
- Eliza, W., Yusmaita, E., Studi, P., Kimia, P., Padang, U. N., Kimia, J., & Padang, U. N. (2021). *Pengembangan Butir Soal Literasi Kimia pada Materi Sistem Koloid Kelas XI IPA SMA / MA*. 5(November).
- Fikrina, Q. A., Sudarmin, S., Pujiastuti, R. S. E., Priatmoko, S., Mahatmanti, F. W., Ulfana, A. R., & Kholis, N. (2023). Development Electronic Worksheet MPPj ETHNO-STEAM to Increase Numeracy Literacy and Conservation Character. *EduChemia (Jurnal Kimia Dan Pendidikan)*, 8(2), 161. <https://doi.org/10.30870/educhemia.v8i2.21554>
- Fitri, I. A., & Iryani, I. (2023). Validitas E-Modul Kimia Sma Kelas Xi Berbasis Problem Based Learning Pada Materi Laju Reaksi Fase F. *Prima Magistra: Jurnal Ilmiah Kependidikan*, 4(4), 579–589. <https://doi.org/10.37478/jpm.v4i4.3221>
- Hariani, N. R., Nuswowati, M., & Winarno, D. (2020). Pengaruh Penerapan Model Inkuiri Terbimbing Berbantuan E-Modul Terhadap Pemahaman Konsep Inkuiri Garam. *Jurnal Inovasi Pembelajaran Kimia*, 14(1), 2561–2571.
- Hariyadi, E., Maryani, E., & Kastolani, W. (2021). Analisis Literasi Lingkungan pada Mahasiswa Pendidikan Geografi. *Gulawentah: Jurnal Studi Sosial*, 6(1), 1. <https://doi.org/10.25273/gulawentah.v6i1.6685>
- Hartanti, W., & Wardhana, K. E. (2023). Membangun Literasi Lingkungan dengan Menerapkan 3R (Reduce, Reuse, Recycle) di TK Nasional KPS Balikpapan. *BOCAH: Borneo Early Childhood Education and Humanity Journal*, 2(1), 1–12. <https://doi.org/10.21093/bocah.v2i1.5631>
- Hazrullah, & Lubis, A. H. (2023). The Interactive Multimedia Based on Theo-Centric Approach as Learning Media during the Covid-19 Pandemic. *JPI (Jurnal Pendidikan Indonesia)*, 12(2), 210–222. <https://doi.org/10.23887/jpiundiksha.v12i2.51493>
- Hidayati Azkiya, M. Tamrin, Arlina Yuza, & Ade Sri Madona. (2022). Pengembangan E-Modul Berbasis Nilai-Nilai Pendidikan Multikultural di Sekolah Dasar Islam. *Jurnal Pendidikan Agama Islam Al-Thariqah*, 7(2), 409–427. [https://doi.org/10.25299/al-thariqah.2022.vol7\(2\).10851](https://doi.org/10.25299/al-thariqah.2022.vol7(2).10851)
- Kusnadi, I. H., Hizraini, A. A., Aswita, D., Munandar, H., & Fathurohman, A. (2023). The Analysis of Online Learning Devices Development Using The PjBL-SteAM Model



- to Improve Student Environmental Literacy. *Journal on Education*, 6(1), 2334–2338. <https://doi.org/10.31004/joe.v6i1.3250>
- Milala, H. F., Endryansyah, E., Joko, J., & Agung, A. I. (2021). Keefektifan Dan Kepraktisan Media Pembelajaran Menggunakan Adobe Flash Player. *Jurnal Pendidikan Teknik Elektro*, 11(02), 195–202. <https://doi.org/10.26740/jpte.v11n02.p195-202>
- Nurhayati, N., Sulastry, T., & Aulia, A. (2023). Pengembangan E-Modul Asam Basa Model Project Based Learning (PjBL) Terintegrasi Science, Technology, Engineering, Art, And Mathematics (STEAM) pada Peserta Didik SMKN 9 Bulukumba. *Chemistry Education Review (CER)*, 6(2), 127. <https://doi.org/10.26858/cer.v6i2.45202>
- Pratiwi, O., Ramadhani, E., & Kuswidianarko, A. (2022). Pengembangan E-Modul Pembelajaran IPA Materi Bumi dan Menjelajah Angkasa Luar Siswa Kelas VI Sekolah Dasar. *Jurnal Pendidikan Dan Konseling*, 4(4), 1397–1403.
- Priatna, A., Latif, A., & Suwarni, W. (2024). Implementation of the Addie Model in the Development of Quartet Game in Understanding Food Security Issues for Children Aged Nine Years and Over. *KnE Engineering*. <https://doi.org/10.18502/keg.v6i1.15363>
- Ririn Santoso, Fenny Roshayanti 2, dan J. S. 3. (2021). Analisis Literasi Lingkungan Siswa SMP. *JPPS (Jurnal Penelitian Pendidikan Sains)*, 10(02), 1976–1982.
- Rosyada, A., Sumarni, W., Nuswowati, M., & Niyamae, A. N. (2025). *Ethno-STEM-Integrated Enriched Chemistry Book to Equip Chemical and Numeracy Literacy*. 6(1), 125–135. <https://doi.org/10.46843/jiecr.v6i1.1930>
- Safitri, R., & Sari, M. (2022). Pengembangan E-Modul Kimia Berbasis SETS (Science, Environment, Technology, And Society) Untuk Siswa Sman 1 Kecamatan Payakumbuh. *Journal of Chemistry Education and Integration*, 1(1), 9. <https://doi.org/10.24014/jcei.v1i1.16245>
- Saragih, P. P., & Tanjung, I. F. (2023). Development of STEM-Based Environmental Change Module to Enhance Environmental Literacy. *Biosfer: Jurnal Tadris Biologi*, 14(1), 89–98. <https://doi.org/10.24042/biosfer.v14i1.17884>
- Spínola, H. (2021). Environmental Culture and Education: A New Conceptual Framework. *Creative Education*, 12(05), 983–998. <https://doi.org/10.4236/ce.2021.125072>
- Sulistiyanti, Dewi, N. K., & Nuswowati, M. (2020). The Development of Environmental Pollution Module by Implementing Laskar Kalpataru Program to Improve Environmental Care Attitude of The Students. *Journal of Innovative Science Education*, 9(1), 50–59. <http://journal.unnes.ac.id/sju/index.php/jise>
- Zandroto, A. V., & Sinaga, K. (2022). Analisis Kemampuan Literasi Kimia Siswa Pada Materi Senyawa Hidrokarbon Melalui Pendekatan Kontekstua. 12, 349–358.
- Zhafirah, T., Erna, M., & Rery, R. U. (2020). Development of E-Module Based on Problem Based Learning (Pbl) in Hydrocarbon Material. *AL-ISHLAH: Jurnal Pendidikan*, 12(2), 216–229. <https://doi.org/10.35445/alishlah.v12i2.263>