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Designing A Socio-Scientific Hypercontent E-Module For Scientific Literacy-Oriented Science Learning In Secondary Level

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Abstract: This study aimed to develop a socio-scientific hypercontent e-module for science learning oriented toward scientific literacy at the secondary education level and to determine its validity, practicality, and effectiveness. This research employed a Research and Development (R&D) approach using the ADDIE model, with Tessmer's formative evaluation during the Development and Evaluation Phases. It consisted of five main phases: Analysis, Design, Development, Implementation, and Evaluation. The development phase consisted of self-evaluation, expert review, one-to-one evaluation, and small group evaluation. The evaluation phase consisted of a field test. The participants were 30 eighth-grade students at SMP Negeri 11 Bayung Lencir. Data were collected through observation sheets, student needs questionnaires, expert validation sheets, student response questionnaires, and scientific literacy tests. The results showed that the developed e-module was categorized as very valid with an average validation score of 95%. The practicality test indicated that the e-module was practical in the one-to-one evaluation (76.6%) and very practical in the small group evaluation (91.8%). The effectiveness evaluation revealed an increase in the average scientific literacy score from 51.2 on the pretest to 87.5 on the posttest, yielding a high N-gain of 0.73. The paired-samples *t*-test also revealed statistically significant improvements across all four scientific literacy competencies ($p < .001$), with the greatest improvement observed in the critical interpretation of data and evidence, followed by evaluating scientific investigation designs, using scientific information for decision-making and action, and explaining scientific phenomena. Therefore, the socio-scientific hypercontent e-module was considered valid, practical, and effective for supporting science learning oriented toward scientific literacy at the secondary level.

Keywords: socio-scientific issues, hypercontent e-module, scientific literacy, science learning, ADDIE model.

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INTRODUCTION

The advancement of science and technology has shifted education from being solely oriented toward mastery of factual knowledge to also fostering higher-order thinking skills, problem-solving abilities, critical reasoning, collaboration, communication, and scientific literacy (Ayuwara et al., 2022; Putri et al., 2025; Yadav et al.,2026). Among these competencies, scientific literacy is one of the most important educational goals because it enables students to understand scientific concepts, evaluate evidence, make informed decisions, and respond critically to complex social and environmental challenges in everyday life (Toharudin et al., 2023; Valladares, 2021). At the secondary education level, scientific literacy is crucial, as students are expected to connect classroom science learning to real-world phenomena and global issues.

Scientific literacy is not only limited to the mastery of scientific knowledge but also includes the ability to explain scientific phenomena,

interpret and analyze data, evaluate scientific arguments, and apply scientific understanding in both personal and social contexts (Auliya, 2024; Toharudin et al., 2023; Wisnu et al., 2025). Large-scale international assessments such as the Programme for International Student Assessment (PISA) consistently place scientific literacy as one of the main indicators of education quality (OECD, 2019, 2023). However, the 2022 PISA results revealed that Indonesia achieved an average science literacy score of 383, substantially lower than the OECD average of 485 and a decline from its 2018 score of 396 (OECD, 2023). Most Indonesian students performed at proficiency level 1a and below, indicating limited scientific knowledge and basic reasoning skills. At these levels, students often experience difficulties in interpreting scientific evidence, evaluating scientific investigations, and applying scientific concepts to real-life situations. These findings are consistent with previous studies reporting that secondary-level students continue to demonstrate relatively low achievement in scientific literacy competencies, particularly in scientific reasoning, interpretation of evidence, and the application of scientific concepts in authentic contexts (Widya et al., 2021). Therefore, science education still faces significant challenges in providing meaningful, contextual, and engaging learning experiences that effectively promote students' scientific literacy.

Preliminary observations at SMP Negeri 11 Bayung Lencir revealed challenges that reflect broader issues in science education. Science instruction remained predominantly teacher-centered, relying heavily on textbook-based explanations and routine exercises, with limited opportunities for students to engage in critical discussions, analyze socio-scientific issues, or apply scientific concepts to real-world situations. Such conventional approaches tend to emphasize memorization and procedural learning rather than inquiry, argumentation, and contextual problem-solving, leading students to perceive science as abstract and disconnected from everyday life (Fibrianto & Venessa, 2025; Ling et al., 2023). Consequently, the development of students' scientific literacy remains limited. A needs analysis further revealed that 86.3% of students preferred digital learning media, 85.9% expressed interest in learning through socio-scientific issues, and 84.2% expected learning materials connected to real-life contexts. These findings underscore the need for innovative instructional resources that foster scientific literacy and promote meaningful, contextually relevant learning experiences. One promising approach is integrating socio-scientific issues (SSI) into digital learning environments, enabling students to examine authentic problems, evaluate scientific evidence, and make informed decisions (Safitri & Suningsih, 2025; Salsabila et al., 2025). To support these processes, digital learning materials should provide flexible access to diverse information sources and interactive learning opportunities (Raharjo et al., 2024). In this regard, hypercontent-based e-modules offer considerable potential by linking students to a variety of digital resources, including videos, articles, interactive activities, and real-world case studies through interconnected hyperlinks and QR codes. Although previous studies have demonstrated the effectiveness of SSI-based learning and hypercontent-based materials independently, research integrating socio-scientific issues, hypercontent technology, and the development of scientific literacy within a single learning resource remains limited, particularly at the junior secondary education level.

In this context, the integration of socio-scientific issues (SSI) into science education is gaining attention as an effective pedagogical approach to enhance scientific literacy (Puspitarini et al., 2025; Yao & Dayana, 2026). Socio-scientific issues are complex and controversial social problems closely related to science and technology, such as climate change, environmental

pollution, biodiversity conservation, energy sustainability, waste management, genetic engineering, and public health (Schenk et al., 2021). SSI-based learning encourages students to analyze scientific evidence, consider ethical and social dimensions, evaluate various perspectives, and construct evidence-based arguments (Kinskey & Newton, 2024; Rahma & Miterianifa, 2023). Through engagement with socio-scientific issues, students not only strengthen conceptual understanding but also develop critical thinking, reflective judgment, decision-making, and a sense of responsible citizenship (Rahma & Miterianifa, 2023; Salsabila et al., 2025).

Previous studies have demonstrated the effectiveness of SSI-based learning in improving students' scientific literacy and higher-order thinking skills. For instance, Arum et al. (2024) integrated SSI through problem-based learning activities that encouraged students to collaboratively discuss and solve real-world scientific problems. Similarly, Prismayadi & Choirunnisa (2024) employed SSI-based classroom discussions to promote critical reasoning and evidence-based decision-making. Although these studies successfully incorporated SSI contexts into science learning, their implementation relied primarily on face-to-face instruction and teacher-guided discussions, providing limited opportunities for students to independently access authentic scientific information through digital learning environments. Furthermore, existing digital learning materials have generally examined SSI, scientific literacy e-modules, and hypercontent as separate approaches. Scientific literacy e-modules developed by Syawaluddin et al (2024) as well as Safitri & Sari (2023) focused on literacy-oriented content but lacked interconnected hypercontent features, whereas hypercontent e-modules developed by Bariyyah et al (2024) and Tharir et al (2022) emphasized creative thinking and spatial abilities rather than scientific literacy within socio-scientific contexts. Consequently, little is known about how integrating SSI, scientific literacy, and hypercontent into a single digital learning environment can support students' engagement with authentic evidence and science-based decision-making. To address this gap, the present study developed a socio-scientific hypercontent e-module that integrates SSI-based activities with videos, news articles, QR-code links, interactive worksheets, and authentic scientific resources within a unified learning environment.

To optimally support the implementation of SSI-based learning, learning resources are needed to facilitate active student engagement in exploring scientific issues in depth and in context. The learning materials must not only convey scientific information but also offer interactive, adaptable, and pertinent learning experiences that align with technological advancements and the traits of contemporary learners. Therefore, the use of digital technology in developing teaching materials is a strategic alternative to support SSI-based science learning oriented toward scientific literacy. The integration of digital technology into the development of science teaching materials also creates opportunities to create more interactive, flexible, and student-centered learning environments (Kerimbayev et al., 2023).

One innovation in digital learning resources is the hypercontent e-module. Hypercontent refers to digital learning content that is interconnected and integrates various forms of media and information sources, such as videos, animations, simulations, hyperlinks, QR codes, interactive assessments, and online references in a single integrated learning environment (Hotimah, 2023; Johan et al., 2022). Unlike conventional electronic modules, which generally present only static textual information, hypercontent e-modules provide a multidimensional learning experience that allows students to actively explore concepts,

access authentic information sources, and learn independently (Fauziah et al., 2022; Tharir et al., 2022).

The integration of hypercontent in SSI-based science learning has great potential to improve students' scientific literacy. Interactive multimedia elements can support conceptual understanding by visualizing abstract scientific phenomena, while access to authentic digital sources enables students to examine real socio-scientific issues from multiple perspectives (Ariyani & Desi, 2026; Crowther, 1999; Mayer, 2009). In addition, hypercontent-based learning environments encourage independent learning, active engagement, inquiry, and reflective thinking, which are important components in the development of scientific literacy. Previous studies have reported that e-modules and hypercontent-based learning media can improve learning outcomes, critical thinking skills, creativity, and students' scientific literacy (Aeni & Widodo, 2022; Humairah et al., 2024; Rufaidah & Nurfadilah, 2021). Furthermore, SSI-based e-modules have also been proven to support science learning oriented towards scientific literacy (Azizah et al., 2022; Faizah & Sugianto, 2025; Hasibuan & Sugiharti, 2025).

Although the implementation of digital technology in education continues to develop, the science teaching materials available at the secondary level still have various limitations. Many e-modules still function merely as digital versions of printed books and have not provided optimal opportunities for students to learn interactively, carry out inquiry activities, or engage in authentic socio-scientific contexts (Islami & Setiawan, 2025; Lastri, 2023; Magdalena et al., 2020). In addition, the integration of scientific literacy dimensions into digital teaching materials remains underdeveloped. Previous studies generally still examine SSI-based learning, scientific literacy e-modules, and hypercontent separately. Researchs on SSI-based learning by Arum et al. (2024) and Prismayadi & Choirunnisa (2024) show that the SSI approach is effective in improving students' collaboration and critical thinking skills. Meanwhile, research on scientific literacy e-modules by Syawaluddin et al. (2024) and Safitri & Sari (2023) has shown that scientific literacy-based e-modules are both feasible and effective for learning. On the other hand, research on hypercontent by Bariyyah et al. (2024) and Pasaribu et al. (2025) reported that hypercontent e-modules could improve students' creative thinking skills and spatial abilities. However, research integrating socio-scientific issues (SSI) with hypercontent e-modules to support science learning oriented toward scientific literacy at the secondary level remains limited. Research that systematically focuses on the design of socio-scientific hypercontent e-modules specifically intended to support science learning oriented toward scientific literacy at the secondary level remains rare.

This gap highlights the need for innovative learning design that integrates pedagogical, technological, and contextual dimensions into a comprehensive learning resource. Therefore, this study focuses on developing a socio-scientific hypercontent e-module for science learning oriented toward scientific literacy at the secondary education level. Thus, this research aims to design a socio-scientific hypercontent e-module that is valid, practical, and effective for use in science learning oriented toward scientific literacy at the secondary level. The developed e-module is also expected to provide an interactive, contextual, and technology-rich learning environment that can support students in developing scientific literacy competencies through engagement with authentic socio-scientific issues. In addition, this research is expected to make both theoretical and practical contributions to the development of digital science learning resources aligned with the demands of 21st-century education and the framework of contemporary scientific literacy. Specifically, this study aims to answer several research questions:

1. What is the validity level of the socio-scientific hypercontent e-module in improving scientific literacy at the secondary level?
2. What is the practicality level of the socio-scientific hypercontent e-module in improving scientific literacy at the secondary level?
3. What is the effectiveness level of the socio-scientific hypercontent e-module in supporting scientific literacy-oriented science learning at the secondary level?

METHOD

Research Design

This research employs a Research and Development (R&D) approach using the ADDIE model, with Tessmer's formative evaluation in the Development and Evaluation Phases. It consisted of five main phases: Analysis, Design, Development, Implementation, and Evaluation. The development phase consisted of self-evaluation, expert review, one-to-one evaluation, and small group evaluation. The evaluation phase consisted of a field test. The ADDIE model was chosen for its systematic, flexible, and structured development procedure, enabling the digital teaching material to be developed in stages from needs analysis to comprehensive product evaluation (Branch, 2009). Moreover, this model is widely used in the development of digital media and teaching materials, as it integrates pedagogical, technological, and user needs within a comprehensive development framework. Meanwhile, Tessmer's formative evaluation complemented the ADDIE model by providing iterative evaluation procedures that support continuous improvement of the product based on expert and user feedback before the final implementation stage (Tessmer, 1993). This research consisted of several phases as follows:

1. Analysis phase

At the analysis phase, a preliminary study was conducted through classroom observation and student needs analysis. The classroom observation aimed to identify current science learning practices, student participation, learning difficulties, and the use of teaching materials in class. Meanwhile, a needs analysis questionnaire was administered to determine students' needs for digital teaching materials oriented toward scientific literacy and integrated with socio-scientific issues.

2. Design phase

At the design phase, learning objectives, flowcharts, storyboards, and a prototype of the socio-scientific hypercontent e-module were developed. The learning objectives were formulated based on scientific literacy competencies and science learning indicators at the secondary education level. These objectives served as the foundation for designing learning activities, assessments, and hypercontent features embedded in the e-module. The learning objectives are presented in Table 1.

Table 1. Learning objectives of the socio-scientific hypercontent e-module

Main Topic	Scientific Literacy Indicator	Learning Indicator	Learning Objective
Food additives	Explaining phenomena scientifically	Identifying types of additives in food and beverage products	Students are able to accurately identify additives based on the examples of food or beverage products provided.
	Interpreting data and evidence critically	Explaining the functions of additives based on information on food packaging labels	Students are able to correctly explain the main functions of additives in food through the analysis of information from food packaging labels.

	Using scientific information for decision-making and action	Classifying additives based on their effects on health	Students are able to correctly classify additives based on their effects through observation results.
Addictive substances and their effects	Explaining phenomena scientifically	Identifying addictive substances in products and the surrounding environment	Students are able to accurately identify addictive substances based on the examples of products or beverages provided.
	Interpreting data and evidence critically	Classifying addictive substances based on their effects on health	Students are able to correctly classify addictive substances based on their effects through observation results.
	Using scientific information for decision-making and action	Analyzing the effects of additive and addictive substance use on health based on real-life cases	Students are able to correctly analyze the effects of additive and addictive substance use on health based on real-life cases.
Healthy lifestyle and decision-making	Interpreting data and evidence critically	Analyzing scientific information related to the effects of additive and addictive substances on health	Students are able to correctly analyze the effects of additive and addictive substance use on health based on real-life cases.
	Using scientific information for decision-making and action	Evaluating decisions to avoid additive and addictive substances through socio-scientific issue-based discussions	Students are able to appropriately evaluate decisions to avoid additive and addictive substances through discussions according to the specified criteria.
	Evaluating scientific investigation designs	Developing simple investigation procedures related to the effects of additive and addictive substances on health	Students are able to accurately design simple investigation procedures related to the effects of additive and addictive substances on health.

The learning activities were designed to engage students in socio-scientific issue (SSI)-based discussions, enabling them to explore different perspectives, evaluate scientific evidence, and formulate informed decisions. The discussion activities served as learning experiences that supported the development of scientific reasoning and decision-making skills. However, the achievement of the learning objectives was assessed through individual scientific literacy tests administered before and after the intervention.

3. Development phase

During the development phase, the e-module prototype was evaluated through several formative evaluation stages: self-evaluation, expert review, one-to-one evaluation, and small-group evaluation. The expert review stage involved media, content, and language experts to assess the product's validity across content quality, media design, language, and instructional aspects. The one-to-one evaluation involved three students with high, medium, and low academic abilities to identify usage challenges and initial student responses to the e-module. Then, the small-group evaluation involved eight students heterogeneous academic abilities to assess the practicality and readability of the developed product.

4. Implementation phase

During the implementation phase, the revised socio-scientific hypercontent e-module

was applied in science learning through a field test over three meetings, each lasting 5 lesson hours. This stage aimed to determine the practicality and effectiveness of the e-module in supporting students' scientific literacy.

5. Evaluation phase

During the evaluation phase, the effectiveness of the e-module and the improvement in students' scientific literacy were assessed using pretest and posttest results. This stage was conducted to determine whether the developed e-module could effectively support science learning oriented toward scientific literacy.

Participants

This research was conducted at SMP Negeri 11 Bayung Lencir during the odd semester of the 2025/2026 academic year. The school was purposefully selected based on several considerations: students' limited understanding of the connection between science concepts and socio-scientific issues, limited use of innovative, digitally based teaching materials, and the dominance of memorization-oriented learning over contextual and inquiry-based learning. These conditions indicate the need for digital teaching materials that can support more interactive, contextual, and scientific literacy-oriented science learning.

Participants in this study were 30 eighth-grade students, consisting of 14 males and 16 females. They were chosen because they represented the target population for implementing and evaluating the SSI-oriented hypercontent e-module in Grade VIII science learning. During the development phase, the one-to-one evaluation involved three students, selected heterogeneously by academic ability (high, medium, and low), who were not part of the main research sample. Then, the small-group evaluation involved eight students, who were also outside the research sample and had heterogeneous academic abilities, to assess the practicality, interactivity, and comprehensibility of the e-module content before it was implemented on a broader scale. The students involved in the one-to-one and small-group evaluation came from the same school and grade level as the field-test participants to ensure comparable prior knowledge and learning experiences.

Prior to data collection, permission to conduct the study was obtained from the Department of Education and Culture of Musi Banyuasin Regency (No. B-830/951/Sekr/Dikbud/2026). Approval was also obtained from the principal and science teachers of SMP Negeri 11 Bayung Lencir. Because the participants were minors, written informed consent was obtained from their parents to participate. Students were informed about the study's objectives and procedures and participated voluntarily. All collected data were anonymized and used solely for research purposes to ensure participant confidentiality and privacy.

Data Collecting Technique

Data in this study were collected using a classroom observation sheet, student needs questionnaires, experts' validation sheets, student response questionnaires, and tests. The classroom observation sheet consisted of 11 items covering five aspects of science learning: lesson planning, instructional practices, student participation, teacher facilitation, and learning constraints. The instrument employed a Guttman scale (Yes/No) to identify the presence or absence of specific classroom conditions, such as the implementation of lesson plans, student participation in learning activities and discussions, teacher facilitation of student-centered learning, and constraints related to learning resources, instructional media, or classroom implementation. Field notes were also used to provide contextual descriptions of the observed conditions.

A student needs questionnaire was administered to determine students' needs and perceptions of the socio-scientific hypercontent

e-module. The needs analysis questionnaire consisted of 20 items, covering aspects such as students' learning styles, needs for teaching materials, and how materials are presented, modified from Safitri & Emiliannur (2025) and Murty (2023).

To assess the validity of the developed socio-scientific hypercontent e-module, expert validation sheets were distributed to media, content, and language experts. Validation scores were rated on a 5-point Likert scale (1 = very poor, 5 = excellent). The media expert validation sheet consisted of 20 items covering visual appearance, media integration, technical aspects, and functionality, adapted from Putri et al. (2020). The content expert validation sheet consisted of 20 items, covering aspects such as material conformity with the curriculum, depth and scientific accuracy, and readability and comprehensibility, also modified from Putri et al. (2020). The language expert validation sheet consisted of 20 items, covering aspects such as language appropriateness, suitability for students' development, and adherence to language rules, modified from Hikmah et al. (2020).

The practicality of the e-module was measured using a student response questionnaire administered during the one-to-one evaluation, small-group evaluation, and field test stages. The student response questionnaire consisted of 16 items covering aspects such as ease of use, clarity of instructions, scientific literacy, appearance, and quality, modified from Andayani & Jakob (2024) and Nurdiyanti et al. (2022). Furthermore, a test instrument was used to determine the effectiveness of the socio-scientific hypercontent e-module.

The test was administered as both the pre-test and post-test. The scientific literacy test consisted of 15 scenario-based multiple-choice items supported by contextual stimuli, such as articles, news reports, tables, graphs, laboratory results, and infographics related to food additives and addictive substances. The instrument was developed based on the OECD (2023) scientific literacy framework used in PISA, covering four competencies: explaining scientific phenomena, interpreting scientific data and evidence, evaluating scientific investigation designs, and using scientific information for decision-making and action, while also incorporating higher-order cognitive processes from the revised Bloom's Taxonomy. Therefore, although the instrument employed a multiple-choice format, the items required higher-order thinking skills, particularly analysis (C4) and evaluation (C5), rather than simple factual recall.

The test instrument was validated on 30 students from the same school but from a different class outside the trial sample. All students were in eighth grade. The trial data were analyzed using IBM SPSS Statistics 27 to calculate item validity (via correlations between item scores and total scores) and internal consistency (using Cronbach's Alpha). The analysis showed that all 15 questions were valid in terms of content and language with a reliability coefficient of $r = 0.769$, indicating a high level of reliability. A summary of the item validity, difficulty, and discrimination analyses is presented in Table 2 with $N = 30$ and $\alpha = 0.05$; the r-table value was 0.361. Items with r-count > 0.361 were considered valid.

Table 2. Item validity, difficulty, and discrimination analysis of the scientific literacy test

Item	r-value	Validity	Difficulty Index (P)	Category	Discrimination Index (D)	Category
1	0.563	Valid	0.784	Easy	0.50	Good
2	0.492	Valid	0.811	Easy	0.40	Good
3	0.413	Valid	0.676	Moderate	0.60	Good

4	0.571	Valid	0.838	Easy	0.50	Good
5	0.389	Valid	0.541	Moderate	0.40	Good
6	0.419	Valid	0.649	Moderate	0.50	Good
7	0.702	Valid	0.784	Easy	0.70	Excellent
8	0.395	Valid	0.432	Moderate	0.40	Good
9	0.504	Valid	0.784	Easy	0.50	Good
10	0.504	Valid	0.784	Easy	0.50	Good
11	0.451	Valid	0.811	Easy	0.50	Good
12	0.699	Valid	0.730	Easy	0.70	Excellent
13	0.395	Valid	0.432	Moderate	0.40	Good
14	0.509	Valid	0.568	Moderate	0.70	Excellent
15	0.368	Valid	0.595	Moderate	0.50	Good

Data Analysis

The observational data were analyzed qualitatively to describe the learning conditions and to identify problems in science teaching practices at the secondary education level. The needs analysis questionnaire data were analyzed quantitatively using percentage calculations to determine students' needs and preferences for digital learning resources. The expert validation data were analyzed quantitatively by calculating the percentage of the total score obtained from the experts' validation sheet relative to the maximum possible score. Then, the percentage results were interpreted using predetermined criteria to determine the validity category (Andayani & Jakob,2024). The practicality data were analyzed quantitatively by calculating the percentage of the total score from student response questionnaires relative to the maximum possible score. Then, the percentage results were interpreted using predetermined practicality criteria to assess the product's practicality level (Nesri & Kristanto, 2020). The test was analyzed using gain scores to assess the effectiveness of the socio-scientific hypercontent e-module. It was examined by using the pretest and posttest results. Then, the gain score results were interpreted using predetermined criteria to determine the product's effectiveness level (Hake, 1998). Then, the pretest and posttest results were analyzed using a paired-samples test in IBM SPSS Statistics 27 to assess improvements in students' scientific literacy.

■ RESULT AND DISCUSSION

Analysis Phase

The analysis phase revealed that, despite alignment with the Phase D Learning Outcomes of the *Merdeka* Curriculum, science instruction remained predominantly textbook-centered and teacher-directed. The limited integration of socio-scientific issues, contextual learning, and digital media restricted students' opportunities to engage in critical discussion, problem-solving, and scientific literacy practices, highlighting the need for more innovative, contextual, and technology-enhanced learning resources. This is corroborated by the results of the students' needs analysis, as presented in Figure 1.

The student's needs analysis indicated a preference for visual, interactive, and contextual learning experiences, particularly through videos, images, discussions, and hands-on activities. However, students showed limited readiness for independent learning, despite being at the early formal operational stage, in which visual and interactive learning can effectively support conceptual understanding (Banda & Nzabahimana, 2023; Voorde & Piroi, 2025). Students also expressed a strong interest in learning connected to real-world social and environmental issues, highlighting the potential to

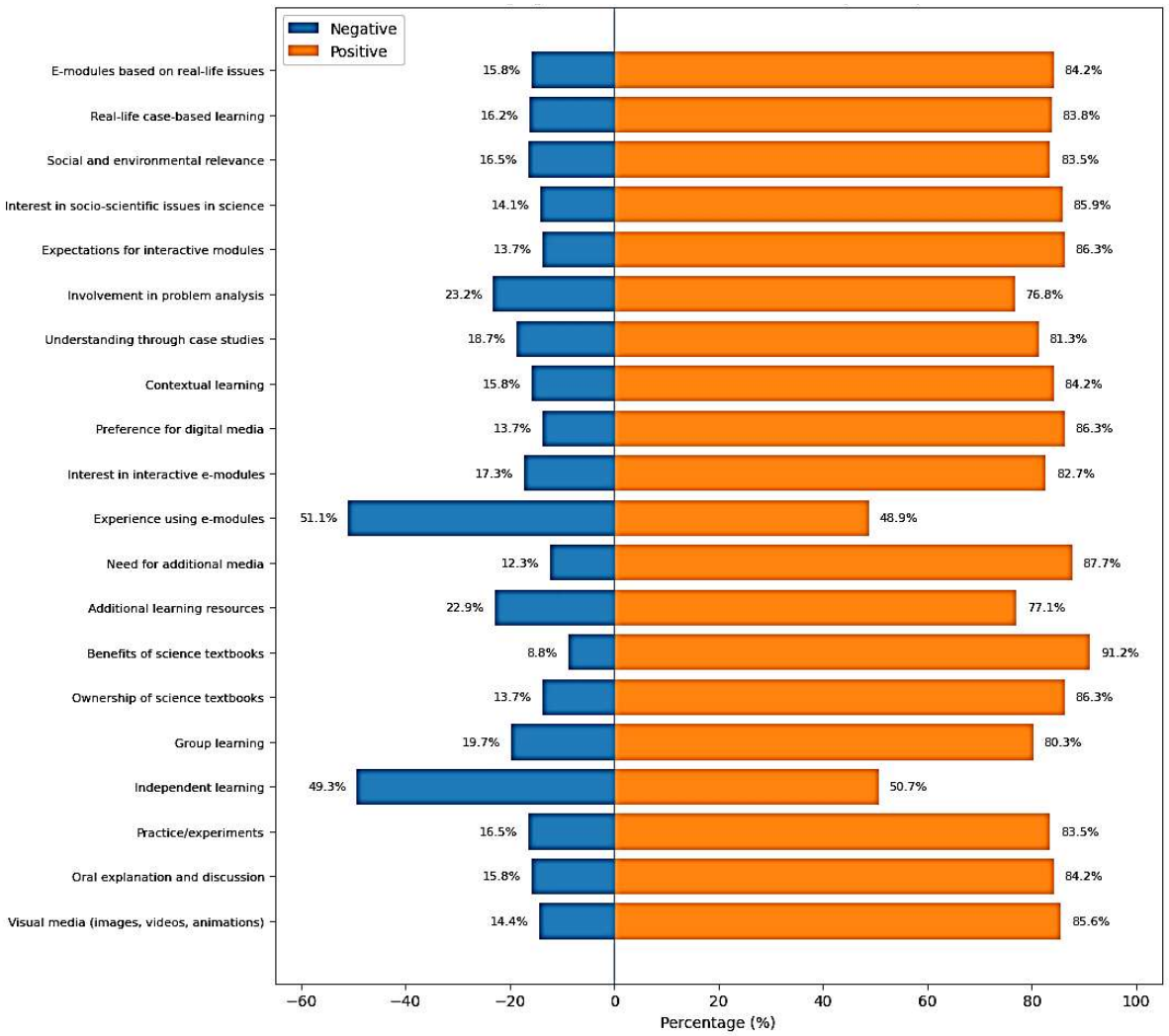


Figure 1. Results of students needs analysis

foster scientific literacy and critical thinking skills. Since SSI-based learning enables students to relate scientific concepts to everyday life while strengthening scientific literacy (Husni et al., 2025), the development of a socio-scientific hypercontent e-module was considered a relevant approach to providing more contextual, engaging, and accessible science learning experiences. In addition, scientific literacy requires students to collect, analyze, and interpret data as part of scientific reasoning (Ariyani & Desi, 2026). Interactive and practical e-modules can also enhance students' engagement and motivation in learning (Safitri et al., 2024). Therefore, the proposed hypercontent e-module was designed to support scientific reasoning, active participation, and scientific literacy through contextual and interactive learning activities.

Design Phase

In the design phase, learning objectives, a flowchart, a storyboard, and a prototype of the socio-scientific hypercontent e-module were developed. The topic of additives and addictive substances was chosen for the development of the socio-scientific hypercontent e-module because it is closely related to students' daily lives and encompasses scientific, health, social, and environmental aspects, making it relevant to supporting contextual learning and strengthening

scientific literacy. The learning objectives formulated for the e-module are presented in Table 1. The e-module was designed to help students understand scientific concepts, analyze the impacts of additives and addictive substances, and evaluate science-based decision-making through socio-scientific issue-based learning. The e-module learning activities were designed in line with the syntax of Problem-Based Learning (PBL), including problem orientation, problem investigation, data collection, collaborative discussion, solution development, and reflection (Ulucinar, 2022).

Figure 2 presents selected storyboards of the final socio-scientific hypercontent e-module interface. The storyboards illustrate the main

Figure 2. User interface of the socio-scientific hypercontent e-module. Product Link: https://share.google/hQdX65oh6e6H3if4Q

navigation page, SSI-based learning activities, and hypercontent features integrated into the module. Through these features, students can access authentic learning resources, including news articles, videos, digital worksheets, and interactive activities. The interface was designed to facilitate independent exploration, contextual learning, and active engagement with socio-scientific issues while supporting the development of scientific literacy skills.

Development Phase

This phase consisted of self-evaluation, expert review, one-to-one evaluation, and small-group evaluation.

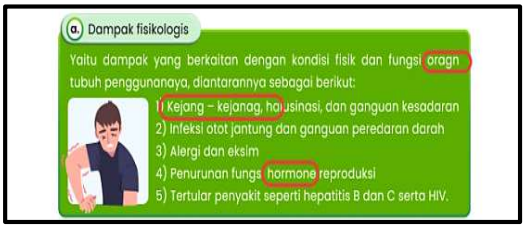
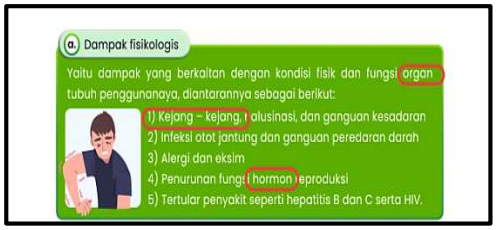
Self evaluation

The self-evaluation stage was conducted prior to expert validation to identify minor issues in the hypercontent e-module. The results indicated that the content, design, navigation, and SSI integration were appropriate, with revisions limited to correcting minor typographical errors before proceeding to the validation stage, as shown in Table 3.

Formative evaluation

The formative evaluation was conducted sequentially to assess and refine the quality of the developed socio-scientific hypercontent e-module prior to field testing. Following Tessmer's formative evaluation model, this phase consisted of three stages: experts' review, one-to-one evaluation, and small-group evaluation. The experts' review assessed the e-module's validity with respect to content, media, and language. The one-to-one evaluation identified usability issues and collected initial feedback from students with

Table 3. Results of self-evaluation

Before	After
	
Several typographical and layout errors were identified in the physiological impact section, including misspelled terms, inconsistent formatting, and unclear text placement, which reduced readability.	The identified errors were corrected by revising the spelling, improving text formatting consistency, and adjusting the layout to enhance readability and ensure accurate presentation of the content.

different levels of academic achievement. Then, the small-group evaluation examined the practicality of the revised e-module in supporting students' learning. A summary of the formative evaluation results is presented in Table 4.

The experts' review results showed that the socio-scientific hypercontent e-module was categorized as highly valid, indicating that it met the quality standards required for science learning oriented toward scientific literacy. Although all

Table 4. The summary of formative evaluation results

Formative Evaluation Phase	Aspect	Obtained Score	Percentage (%)	Category
Experts' Review	Media Validation	98	98.0	Very Valid
	Content Validation	88	88.0	Very Valid
	Language Validation	99	99.0	Very Valid
Small Group Evaluation	Ease of Use	142	88.8	Very Practical
	Clarity of Instructions	151	94.4	Very Practical
	Scientific Literacy	178	89.0	Very Practical
	Appearance and Quality	114	95.0	Very Practical

aspects received positive evaluations, the content aspect was rated relatively lower than the language and media aspects. Validators identified several areas for improvement, including the need for a more explicit alignment between socio-scientific issues and scientific literacy indicators, the incorporation of additional supporting scientific references, and the inclusion of more diverse activities that promote evidence-based reasoning. According to instructional design principles, the quality of learning materials depends not only on conceptual accuracy but also on their ability to engage learners meaningfully with scientific concepts and authentic real-world issues (Branch, 2009; Tomlinson, 2023). Furthermore, effective science learning materials should facilitate connections between scientific knowledge and real-life contexts while fostering higher-order thinking skills (OECD, 2023). Consequently, revisions were undertaken to strengthen the integration of socio-scientific contexts, enhance the depth and accuracy of

scientific explanations, and provide greater opportunities for students to analyze evidence and make informed decisions.

The developed e-module was structured, aligned with learning objectives, used clear, communicative language, and was supported by attractive visual presentations through images and videos, thereby helping students understand concepts more effectively (Amalia & Kuntjoro, 2026). This finding was consistent with the research by Syawaluddin et al. (2024), which stated that hypercontent-based e-modules could present material more attractively by integrating various digital media. Furthermore, Bariyyah et al. (2024) explained that hypercontent e-modules could help students better understand the material because they were interactive, systematic, and easy to understand.

The one-to-one evaluation involved three students representing high, moderate, and low academic achievement levels, as classified by their science scores from the previous semester. This stage was conducted to identify usability issues and gather direct feedback before proceeding to the small-group evaluation. The three participants required approximately 120 minutes to complete all learning activities within the e-module. Overall, they reported that the e-module was visually appealing, easy to use, and supported independent learning through its interactive features and hypercontent resources. However, several suggestions for improvement were identified during this stage.

One participant reported difficulty recognizing the instructions for learning activities because commands such as "click the button," "upload," "start," and "begin" were presented in regular text and did not stand out from the surrounding content. As a result, students occasionally felt uncertain when moving on to the next learning activity. In response, these instructional commands were reformatted in bold type to improve their visibility and facilitate navigation. Another participant identified an error in the hyperlink associated with the "Let's Understand Real Issues!" activity in Chapter 3. The link directed students to the same resource used in Chapter 2, potentially limiting access to the intended learning content. This issue was subsequently corrected to ensure that each activity was linked to the appropriate socio-scientific resource. The last participant experienced difficulty interpreting evidence presented in the SSI article on page 13. Therefore, additional guiding questions and explanatory notes were inserted to reduce misconceptions and support scientific reasoning.

Students reported that integrating socio-scientific issues and real-life contexts helped them connect scientific concepts to everyday phenomena, making learning more meaningful and relevant. However, some students still had difficulty interpreting data and drawing conclusions independently. Based on the feedback, minor revisions were made, including improving the visibility of instructional commands and correcting repeated activity links. These findings suggest that clear navigation, effective content organization, and well-designed multimedia features can enhance student engagement, independent learning, and conceptual understanding (Asri et al., 2024; Faisal et al., 2025; Mayer, 2009). The revisions also improved the e-module's usability and functionality prior to the small-group evaluation.

Then, the small-group evaluation was conducted with 8 students, comprising 2 students with high ability, 3 with moderate ability, and 3 with low ability. In the small-group evaluation, the developed e-module demonstrated a practicality level of 91.8%, indicating that it was easy to use and supported students' independent learning. The effectiveness of the revisions implemented after the one-to-one evaluation was reflected in the reduced completion time, from approximately 120 minutes to 90 minutes. This

improvement suggested that enhanced navigation instructions and corrected hypercontent links enabled students to access learning resources more efficiently and complete activities with fewer difficulties. Furthermore, students were able to follow the learning sequence and utilize hypercontent features with minimal assistance. These findings are consistent with previous studies reporting that well-designed e-modules support independent learning by providing engaging content and flexible access to learning resources (Maulida et al., 2024; Safitri & Sari, 2023).

Implementation Phase

During the implementation phase, the socio-scientific hypercontent e-module was field-tested with Grade VIII students at SMP Negeri 11 Bayung Lencir over three meetings using the Problem-Based Learning model. Students accessed the e-module through their personal smartphones and interacted with hypercontent features, including QR-code-linked videos, digital worksheets, Google Forms, Padlet, and interactive games. Learning activities focused on food additives and engaged students in analyzing authentic socio-scientific issues, interpreting scientific information, discussing evidence, and proposing solutions to real-world problems. The implementation promoted active participation, contextual learning, and stronger connections between scientific concepts and everyday life (Markula & Aksela, 2022; Maulida et al., 2024; Ondog et al., 2024).

Evaluation Phase

The evaluation was conducted after the e-module was implemented in the classroom. Students completed the pre-test before the learning activities began and the post-test after the learning was completed. Figure 3 presents the distribution of individual pretest and posttest scores.

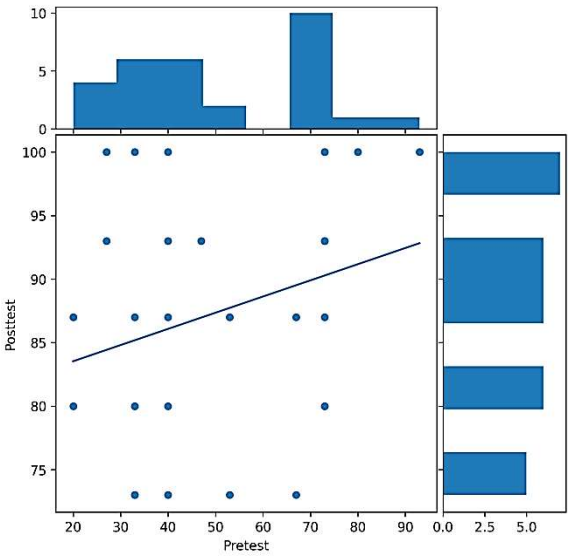


Figure 3. Marginal histogram scatter plot in score distribution

The marginal histograms reveal a clear rightward shift in score distribution, with pretest scores predominantly concentrated between 20 and 53 and posttest scores clustered between 80 and 100, indicating substantial improvement in students' scientific literacy following the implementation of the socio-scientific hypercontent e-module. The Shapiro–Wilk test confirmed that the difference scores were normally distributed ($W = 0.943$, $p = 0.106$), supporting the use of a paired-samples *t*-test for subsequent analysis. The scatter plot shows a weak positive association between pretest and posttest scores. At the same time, the broad dispersion of data points indicates that students with lower initial achievement also attained high posttest scores. Overall, the visual evidence suggests that learning gains were achieved across students with diverse prior knowledge.

These findings also demonstrate the intervention's effectiveness in enhancing students' scientific literacy. The reported N-gain (0.73) was calculated from the average class pretest score (51.2) and posttest score (87.5) and was

categorized as a high learning gain. To further illustrate the distribution of individual learning gains, Figure 4 presents the frequency distribution of normalized gain (N-gain) categories, showing the proportions of students who achieved high, moderate, and low levels of improvement following the intervention.

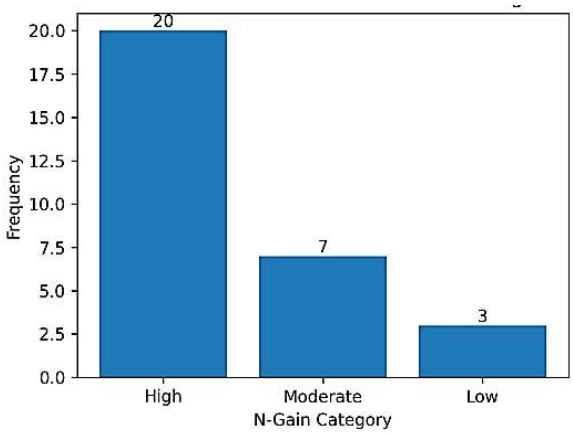


Figure 4. Distribution of students across n-gain categories

The predominance of high N-gain scores indicates that the socio-scientific hypercontent e-module effectively promoted substantial improvements in students' scientific literacy. Furthermore, the relatively small proportion of students in the low N-gain category suggests that the intervention benefited the majority of students, regardless of their initial achievement level. These findings are consistent with previous studies highlighting the effectiveness of hypercontent e-modules and socio-scientific issue (SSI)-based learning approaches in improving students' competencies. For instance, Pasaribu et al. (2025) reported that hypercontent e-modules significantly enhanced students' learning outcomes, while Arum et al. (2024) and Prismayadi and Choirunnisa (2024) demonstrated that SSI-based learning effectively improved students' collaboration and critical thinking skills. The present study extends this body of evidence by demonstrating substantial improvements in scientific literacy through the implementation of an SSI-oriented hypercontent e-module. To further investigate the significance of these improvements, a paired-samples t-test was conducted to compare pretest and posttest scores for each scientific literacy indicator, as shown in Table 5 below.

Table 5. The result of improvement in scientific literacy

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Post-Pre Indicato 1	.60000	.72397	.13218	.32966	.87034	4.539	29	< .001
Post-Pre Indicator 2	3.26667	1.99885	.36494	2.52028	4.01305	8.951	29	< .001
Post-Pre Indicator 3	.66667	.80230	.14648	.36708	.96625	4.551	29	< .001
Post-Pre Indicator 4	.80000	.76112	.13896	.51579	1.08421	5.757	29	< .001

All scientific literacy indicators showed statistically significant improvements following implementation of the socio-scientific hypercontent e-module ($p < .001$). However, the magnitude of improvement varied across indicators, with indicator 2 (interpreting data and evidence critically) demonstrating the largest mean gain, followed by indicator 4 (evaluating scientific

investigation designs), indicator 3 (using scientific information for decision-making and action), and indicator 1 (explaining phenomena scientifically). The greater improvement observed in the critical interpretation of data and evidence reflects the learning activities' emphasis on analyzing socio-scientific issues through videos, news articles, food labels, and case studies. These authentic learning experiences required students to analyze evidence, interpret scientific information, and justify decisions, thereby promoting higher-order thinking while connecting scientific concepts to real-world contexts. Although indicators 1, 3, and 4 also improved significantly, their relatively smaller mean gains suggest that these competencies may benefit from more sustained practice and additional inquiry-oriented learning experiences. Overall, the results indicate that the socio-scientific hypercontent e-module effectively enhanced multiple dimensions of students' scientific literacy while revealing differences in the extent of improvement across specific competencies.

These results are consistent with those reported by Aeni and Widodo (2022), who found that interactive e-modules enhance students' engagement through multimedia-based learning. However, the present study extends this evidence by demonstrating the added value of integrating hypercontent into socio-scientific learning. Unlike conventional interactive e-modules, which typically provide learning materials and exercises within a single platform, the developed e-module connected students to multiple authentic learning resources, including videos, news articles, digital worksheets, and interactive games. This interconnected learning environment enabled students to independently explore real-world socio-scientific issues, critically evaluate evidence from multiple sources, and engage in collaborative decision-making, thereby supporting the development of scientific literacy across multiple competencies.

The novelty of this study lies in the development of a socio-scientific hypercontent e-module that integrates socio-scientific issues and scientific literacy within an interconnected learning environment. Although previous studies have incorporated socio-scientific issues to improve scientific literacy, they have generally not integrated hypercontent to connect multiple learning resources into a coherent learning experience. In this study, socio-scientific issues served as authentic learning contexts, while scientific literacy represented the primary learning outcome. Hypercontent functioned as a technological bridge that enabled students to access various learning resources, such as texts, videos, and interactive links, thereby facilitating meaningful connections among scientific concepts. Consequently, the developed e-module not only delivered instructional content but also helped students relate scientific concepts to real-world problems while developing the competencies required for scientific literacy.

Overall, the findings demonstrate that designing a socio-scientific hypercontent e-module is an effective approach to science learning oriented toward scientific literacy at the secondary level. By integrating authentic socio-scientific issues with interconnected digital learning resources, the developed e-module promoted meaningful, contextual, and student-centered learning while strengthening multiple dimensions of scientific literacy. These findings contribute to the growing body of research on technology-enhanced science education by demonstrating how hypercontent can support scientific literacy-oriented learning through authentic, evidence-based, and digitally connected learning experiences.

The implications of this study highlight the importance of developing contextual, innovative, and technology-integrated digital teaching materials to strengthen students' scientific literacy. The findings also provide practical guidance for

teachers and educational practitioners in designing science learning that is meaningful and aligned with the objectives of the *Merdeka* Curriculum. Future research should evaluate the e-module across a wider range of schools, include more diverse samples, and examine its long-term effects on students' scientific literacy and critical thinking skills. Future studies should also incorporate more inquiry-oriented activities, such as investigation design tasks, virtual experiments, and scientific explanation exercises, to further strengthen students' scientific literacy competencies. In addition, future research could investigate the integration of the socio-scientific hypercontent e-module into STEM education, inquiry-based learning, or other digital learning environments to further enhance students' engagement and scientific reasoning skills.

CONCLUSION

The findings of this study indicate that the SSI-oriented hypercontent e-module met the criteria of validity, practicality, and effectiveness for science learning oriented toward scientific literacy. Experts' review confirmed that the e-module was highly valid in terms of content, media design, and language use, demonstrating its suitability as a contextual and interactive digital learning resource. One-to-one and small-group evaluations showed that the e-module was highly practical. Students found it easy to use, visually engaging, and supportive of independent learning through the integration of videos, interactive games, digital worksheets, and other hypercontent features. The potential effect evaluation indicated that the e-module effectively enhanced students' scientific literacy, as evidenced by a high N-gain score (0.73) and improved posttest performance. Furthermore, the paired-samples *t*-test revealed statistically significant improvements across all four scientific literacy competencies ($p < .001$), with the greatest improvement observed in critically interpreting data and evidence, followed by evaluating scientific investigation designs, using scientific information for decision-making and action, and explaining scientific phenomena.

Overall, the findings suggest that integrating socio-scientific issues with hypercontent technology can support more contextual, interactive, and student-centered science learning while strengthening key dimensions of scientific literacy. Future research should involve larger and more diverse samples, longer implementation periods, and more inquiry-based learning activities to further enhance students' competencies in scientific explanation and investigation design.

DECLARATION OF GENERATIVE AI USAGE IN THE WRITING PROCESS

During the writing of this manuscript, the authors employed Grammarly to assist with language refinement/proofreading. The authors have reviewed and edited the content generated by this tool and assume full responsibility for the published article.

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