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The Application of Local Potential-Based E-Modules to Improve Students Critical Thinking Skills in Biology Learning: A Systematic Literature Review

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Abstract: The application of e-modules based on local potential in biology learning is an innovation that can integrate science with the local environment. This study aims to analyze the influence, effectiveness, and challenges of applying e-modules to improve critical thinking skills. A systematic literature review was adopted as the research method after selecting and screening articles using the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) protocol. Articles published from 2017 to 2026 were retrieved from Scopus. Of the 109 articles identified, 11 articles were selected based on inclusion and exclusion criteria. The results show that electronic modules based on local potential are effective in improving students' critical thinking skills, scientific literacy, problem solving, and other 21st-century skills. The integration of local potential can help students connect scientific concepts with everyday life, creating more relevant and in-depth learning based on reality. However, challenges remain in terms of digital literacy, design, and curriculum suitability. This study is expected to serve as the basis for the development of contextual biology e-modules oriented towards higher-order thinking skills.

Keywords: Biology; Critical thinking; E-module; Local potential; Systematic literature review

Introduction

Technological and scientific developments in the 21st century require not only a focus on mastering concepts but also on developing higher-order thinking skills, particularly critical thinking. Critical thinking is seen as an important skill that enables students to critically analyze information, evaluate arguments, and make rational and reflective decisions when dealing with complex and abstract problems or topics (Facione, 2015). In biology learning, critical thinking skills are increasingly important because the material and topics are abstract and complex. According to Zohar & Dori (2003), biology learning in schools still tends to be oriented towards memorizing concepts and delivering material in a conventional manner, and is not yet optimal in developing critical thinking skills in students. Based on direct observations of one teacher when the researcher or author conducted observations, it was found that in several schools, the teaching materials used were not contextual and did not relate biological concepts to the realities of students' lives. Therefore, learning innovations are needed that not only utilize technology but are also relevant to the social, local, and environmental contexts in which students live.

Teaching materials are an important component in teaching activities to achieve the competencies that students are expected to master. The use of appropriate teaching materials can facilitate the learning process (Nur & Lili, 2022; Novianti et al., 2023). However, current learning materials are still lacking in interactivity and innovation. Teachers still use printed teaching materials provided by the government and do not prioritize a contextual approach, causing students to quickly become bored when studying. Entering the current digital era, education needs to adapt to

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technological developments and advances so that the potential of technology can create new learning spaces that are more enjoyable and can improve 21st-century skills because students are motivated to learn (Marta, 2019). In addition, teachers must also have teaching strategies that can provide freedom to learn actively in the learning process with various forms of approaches and learning models that are in accordance with the needs of the student environment in order to achieve deep learning objectives (Altinyelken & Hoeksma, 2021).

One approach that is considered to have the potential to address the various challenges in education today is the development and application of locally-based e-modules for students' environments. E-modules are digital teaching materials designed for independent or guided learning, equipped with interactive features, multimedia, visualizations, and learning activities that are clearly structured, relevant to the learning topic, and flexible (Sung et al., 2016). In biology learning, e-modules enable the presentation of abstract concepts through visualization, simulation, and virtual experiments that can support higher-order thinking processes. The integration of local potential or local wisdom in e-modules can add value to the quality of learning. According to Aikenhead (2006) in his book, local potential includes knowledge, practices, natural resources, and culture that have developed in the local community and are relevant to scientific concepts. Local potential can also take the form of regional biodiversity, the use of traditional medicinal plants, local agricultural practices, and environmental issues surrounding students. Learning that can link biological concepts to the local context is believed to increase the meaningfulness of learning, strengthen conceptual understanding, and encourage deeper cognitive engagement among students (Gilbert & Gilbert, 2007).

Context-based learning is in line with the context-based learning approach and constructivist learning theory, which emphasizes that knowledge is constructed through active interaction between learning experiences and the students' socio-cultural environment (Gilbert & Gilbert, 2007). When local context is integrated into e-modules, students not only learn abstract biological concepts but are also guided to analyze real phenomena, evaluate environmental issues, and formulate solutions based on scientific reasoning. Previous studies have shown that e-modules based on local issues, problems, or the students' surrounding environment can have a positive influence on critical thinking skills (Dewi et al., 2017; Pitorini, 2025). Furthermore, interactive digital e-modules based on local wisdom are effective in developing critical thinking (Makhrus et al., 2025; Syahfitri & Muntahanah, 2024). However, the results of these studies show variations in e-module design, pedagogical approaches, and local context. Furthermore, not all studies specifically focus on biology learning, and the use of e-modules in the teaching and learning process is not yet optimal. This condition indicates the need for a comprehensive study that can synthesize empirical findings systematically and critically.

Students will find it easier to understand material and information if it is relevant to their surroundings. For example, in Yoshiyama et al. (2019) study on natto production in biotechnology, this practicum can improve 21st-century skills, namely scientific literacy and creativity. Therefore, it is important for teachers to utilize local potential in learning to help students understand concepts and examples contextually and to improve students' skills and knowledge. Therefore, this systematic literature review research is important and relevant in synthesizing empirical findings, identifying research trends, and formulating the direction of development and application of e-modules based on local potential that are more oriented towards improving students' critical thinking skills based on the reality and environment around students. The results of this study are expected to contribute theoretically and practically to the development of contextual digital teaching materials in the learning process.

Method

This study used the Systematic Literature Review (SLR) method, which employs the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) protocol to obtain in-depth references (Ekici, 2021). The research method was carried out by systematically identifying journals or articles by applying four stages, namely search strategy (identification), selection criteria (screening), quality assessment (feasibility), and inclusion (Moher et al., 2009). The first stage of this research was to select the title or theme to be studied, and the second stage was to formulate the problem in the form of a question, known as the research question. The research question (RQ) in this study was:

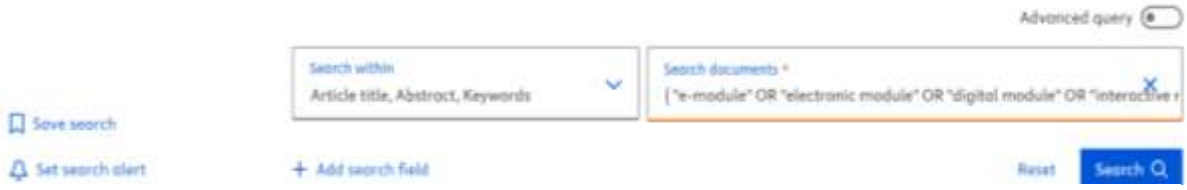
RQ1: How does the application of e-modules based on local potential affect the improvement of students' critical thinking skills in biology learning?

RQ2: How effective are local potential-based electronic modules in the biology learning process in improving students' critical thinking?

RQ3: What are the challenges faced in the application of local potential-based e-modules in biology learning?

The next step is to identify criteria for finding high-quality scientific articles relevant to the topic. This identification stage involves determining the keywords used to search for the required research articles. Based on the participant, intervention, comparison, and

outcome (PICO) framework and adjusted to the research objectives from reputable databases and the 2017-2026 time frame (Mamédio et al., 2007). The database used in this study is the Scopus database for the last 10 years from 2017 to 2026, covering high-quality journal publications. The publications found in these databases are scientific articles (Haseski et al., 2018). The next step is to determine the PICO used to identify keywords for systematic reviews in various data (Cooke et al., 2012). The selected keywords (Table 1) for each PICO component were used to find the desired research articles using Boolean operators such as AND and OR (Figure 1) for example searches in Scopus. At this stage, 109 articles based on Scopus data were found.



TITLE-ABS-KEY ("e-module" OR "electronic module" OR "digital module" OR "interactive module" OR "local Potential" OR "Etnosains") AND ("critical thinking" OR "critical thinking skills" OR "higher-order thinking" OR "HOTS") AND ("education OR learning OR teaching OR instruction OR students")

Figure 1. Example of search strategy

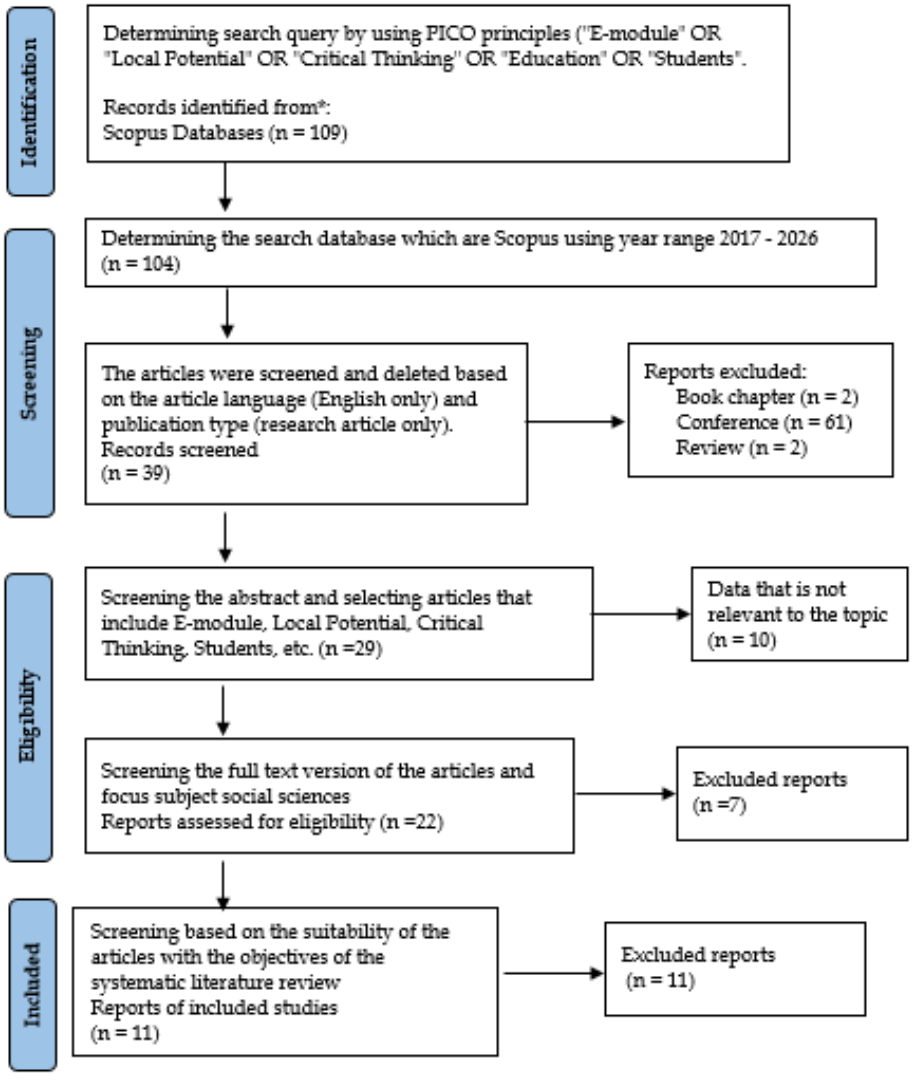


Figure 2. Article selection flow with PRISMA

Table 1. Keywords based on PICO principles

PICO aspects	Keywords
Participants	"students", "learner", "secondary school students", "high school students", "senior high school".
Intervention	"e-module", "electronic module", "digital module", "interactive module", "digital learning", "local potential", "local wisdom", "local-based learning", "ethnoscience".
Comparison	-
Outcome	"critical thinking", "learning", "teaching", "biology education", science education".

The screening stage began with selecting articles collected in the identification stage based on language, publication type, publication year within the last ten years, and keywords based on topic. At this stage, only articles written in English were selected, as it is an international language, making it easier for researchers to analyze and synthesize the articles found. The search results are depicted in a PRISMA diagram, and the data is then analyzed by fulfilling the inclusion criteria and assessing the quality of descriptive research in accordance with the main key topics to provide an overview of the research questions. The article feasibility and inclusion analysis stage involves selecting articles based on their titles and abstracts and then selecting articles based on their writing quality to ensure they are relevant to the target topic. The basic steps are visualized in Figure 2.

Result and Discussion

Based on the research method using PRISMA, 109 articles were obtained from Scopus by referring to keywords and selected based on four stages, namely search strategy (identification), selection criteria (screening), quality assessment (feasibility), and inclusion. Eleven articles were obtained for further review in accordance with the objectives and focus of the research topic (Table 2).

Table 2. Database of 11 articles selected from PRISMA

Author's name	Title
Dewi et al. (2017)	The effect of science learning integrated with local potential of wood carving and pottery towards the junior high school students' critical thinking skills.
Syahfitri & Muntahanah (2024)	The effectiveness of local wisdom-based interactive digital module on students' critical thinking disposition.
Pertiwi et al. (2024)	Enhancing critical thinking skills through stem problem-based contextual learning: an integrated e-module education website with virtual experiments.
Makhrus et al. (2025)	Effect of e-modules based on sustainable development goals (sdgs) with the conceptual change model-cognitive conflict approach (ccm-cca) integrated with local wisdom on students' critical thinking skills.
Nurhidayati et al. (2024)	The design of project-based learning model based on local potential and social constructive investigation and its impact on students' green behavior.
Aliyah & Widiyatmoko (2022)	Entrepreneurship-based biotechnology e-module development to improve critical and creative thinking skills.
Pitorini (2024)	Students' critical thinking skills using an e-module based on problem-based learning combined with socratic dialogue.
Suryawati et al. (2024)	First-year undergraduate biology education students' critical thinking and self-regulation: implementation of a metacognitive-based e-learning module.
Pitorini (2025)	Using an e-module based on problem-based learning combined with socratic dialogue to develop students' critical thinking skills: a qualitative study.
Serevina et al. (2022)	Improving the quality of education through the effectiveness of an android-based e-module for enhancing students' critical thinking skills in the pandemic era.
Salampessy & Suparman (2020)	Design of a probability module based on the pbl learning model to improve critical thinking skills.

Analysis of Article Suitability with Research Topic Focus

Based on the synthesis of the 11 final PRISMA articles, all articles reveal that there is a positive effect of e-module implementation on students' critical thinking skills, both significantly and descriptively. However, the level of relevance to biology learning and local potential varies considerably. This can be seen in Table 3.

Table 3. Analysis of article suitability

Author's name	Research focus and objectives	Relevance to topic and reasons
Dewi et al. (2017)	Examining the effect of science learning integrated with local potential (wood carving & pottery) on the critical thinking skills of junior high school students	(relevant) Integrating local potential and measuring critical thinking skills, although not yet in the form of digital e-modules and conceptual.

Author's name	Research focus and objectives	Relevance to topic and reasons
Syahfitri & Muntahanah (2024)	Evaluating the effectiveness of interactive digital e-modules based on local wisdom on students' critical thinking skills	(highly relevant) Directly addressing e-modules+local potential+critical thinking, highly aligned with the research topic
Pertiwi et al. (2024)	Developing stem-based e-modules and contextual learning with virtual experiments to enhance critical thinking	(relevant) Using contextual e-modules, although local potential is not explicitly mentioned, it is still relevant as a contextual approach
Makhrus et al. (2025)	Testing sdg-based e-modules integrated with local wisdom and ccm-cca on critical thinking	(highly relevant) Integrating e-modules, local wisdom, and critical thinking, and relevant to biology and sustainability issues.
Nurhidayati et al. (2024)	Designing PBL based on local potential and social investigation on environmentally friendly behavior	(moderately relevant) The main focus is on green behavior rather than critical thinking, and it is used as indirect conceptual support.
Aliyah & Widiyatmoko (2022)	Discusses PBL based on local potential in the context of education	(quite relevant) Based on local potential, but does not use digital e-modules and critical thinking is not a major variable either.
Pitorini (2024)	Measuring students' critical thinking skills through PBL-based e-modules and socratic dialogues	(fairly relevant) Strengthening the role of e-modules in critical thinking, even without the context of local potential
Suryawati et al. (2024)	Implementation of a metacognitive-based e-learning module to improve critical thinking and self-regulation among biology students	(supporting relevance) Relevant to biology and critical thinking but not based on local potential
Pitorini (2025)	Qualitative study of pbl and socratic dialogue e-modules on critical thinking	(relevant supporting evidence) Provides an in-depth look at the critical thinking process, but the local context is not highlighted
Serevina et al. (2022)	Effectiveness of android-based e-modules on students' critical thinking	(limited relevance) Focuses on technology and critical thinking without any biological context or local potential
Salampessy & Suparman (2020)	PBL modules on probability to improve critical thinking	(less relevant) Not biology, not an e-module based on local potential, used only as a general methodological reference

RQ1. How Does the Implementation of E-Modules Based on Local Potential Affect the Improvement of Students' Critical Thinking Skills in Biology Learning?

A synthesis analysis of the articles (Table 4) shows that the application of e-modules based on local potential can have a positive and consistent effect on improving students' critical thinking skills, especially at higher levels of thinking such as analysis, evaluation, and conceptual reflection. In biology learning, abstract concepts such as ecosystems, biodiversity, or sustainability are often difficult to understand in depth. Concepts linked to local potential are close to students' lives, and the thinking process can understand definitions leading to critical scientific reasoning. Critical thinking develops optimally when learning is contextual and meaningful (Facione, 2015).

The findings of Dewi et al. (2017) show that the integration of local potential can significantly improve students' critical thinking. Students are encouraged to observe, analyze, and evaluate local-based learning processes around them from a scientific perspective. This indicates that local potential serves as an initial cognitive stimulus that can activate prior knowledge and encourage analytical thinking. Theoretically referred to as contextual teaching and learning, it states that learning associated with real contexts can improve higher-order critical thinking skills because students are involved in the process of interpreting and evaluating meaning (Johnson, 2002). In the context of biology, these local phenomena allow students to relate scientific concepts to ecological and social realities, so that critical thinking develops naturally.

A stronger influence is seen in the research by Syahfitri & Muntahanah (2024) and Makhrus et al. (2025), which explicitly uses locally-based digital e-modules. E-modules not only present content, but also provide cognitive interactive space through provocative questions, simulations, and reflective activities. Interactive and contextual digital modules are more effective in developing critical thinking than static teaching materials (Fu & Hwang, 2018). In addition, the study by Makhrus et al. (2025), provides evidence that problems or issues cognitively associated with local phenomena are an important mechanism in improving critical thinking. When students are confronted with differences between their initial understanding and contextual reality, they will be encouraged to evaluate and reconstruct concepts based on the reality and experiences of their surroundings (Vosniadou, 2013). Problem-based learning also significantly improves students' analytical and decision-making skills so that through local potential, it can have an influence as the

most relevant and contextualized form of students' daily lives in biology learning (Kong, 2015).

Table 4. Analysis of the impact of implementing local and critical e-modules

Author's name	Form of intervention	Impact
Dewi et al. (2017)	Integrated science learning using local potential (wood carving & pottery)	The local context can facilitate cause-and-effect analysis and scientific process evaluation as well as authentic experiences that can improve reflective learning.
Syahfitri & Muntahanah (2024)	Interactive digital e-modules based on local wisdom	The integration of local content and e-module interactivity encourages independent exploration, argumentation, and critical thinking skills.
Pertiwi et al. (2024)	Contextual stem e-modules with virtual experiments	Contextual learning and stem problem solving can strengthen analysis and inference despite implicit local potential
Makhrus et al. (2025)	SDGs e-modules integrated with local wisdom and critical thinking	Through the existence of cognitively-based problems rooted in the local context, it can encourage the evaluation of arguments and the critical reconstruction of concepts.
Nurhidayati et al. (2024)	PBL model based on local potential and social constructive investigation	Project activities based on local potential require students to analyze environmental issues, evaluate alternative solutions, and synthesize knowledge, thereby indirectly improving critical thinking skills through investigative and reflective processes.
Aliyah & Widiyatmoko (2022)	Entrepreneurship-based biotechnology e-module	The context of entrepreneurship based on local potential encourages students to critically assess biotechnology processes, scientific decision-making, and impact evaluation, which contributes to the improvement of critical and creative thinking.
Pitorini (2024)	Problem-Based Learning (PBL)-based e-module combined with Socratic Dialogue	Open-ended problem structures and reflective dialogue encourage students to develop arguments, cause-and-effect analysis, and evidence evaluation, thereby significantly improving critical thinking skills.
Suryawati et al. (2024)	Metacognitive-based e-learning module for biology education students	The metacognitive approach trains awareness of the thinking process, monitoring of understanding, and evaluation of learning strategies, which strengthens students' critical thinking and self-regulation.
Pitorini (2025)	Qualitative study of PBL e-module with Socratic Dialogue	Dialogic interaction and deep reflection help students build critical conceptual understanding and improve the quality of scientific reasoning.
Serevina et al. (2022)	Android-based interactive e-module	The interactivity and flexibility of e-modules encourage independent exploration, information analysis, and answer evaluation, thereby improving critical thinking even when the local context is not dominant.
Salampessy & Suparman (2020)	Problem-Based Learning-based module	The presentation of contextual problems and PBL stages facilitates the ability to analyze, infer, and evaluate solutions, which has a positive impact on students' critical thinking skills.

RQ2: How Effective is the Locally-Based Electronic Module in the Biology Learning Process in Enhancing Students' Critical Thinking?

Based on an analysis of the 11 main articles related to the effectiveness of e-modules in the learning process (Table 5), it was found that local potential-based electronic modules were effective to highly effective in improving students' critical thinking skills in biology learning. This effectiveness was reflected in a significant increase in various critical thinking indicators, including the processes of analysis, inference, and conceptual reflection. In general, the effectiveness of e-modules based on local potential is higher than conventional learning or generic digital modules, because e-modules not only present information but also facilitate higher-order thinking processes through authentic real-world contexts. This is in line with the view that the effectiveness of learning is measured not only by learning outcomes but also by the depth of the cognitive processes that occur in the learning process (Biggs & Tang, 2011).

Theoretically, contextual learning also increases effectiveness because students find it easier to relate new knowledge to their initial understanding and experiences, so that the analysis and evaluation processes are more in-depth (Ausubel, 1968). According to Syahfitri & Muntahanah (2024), in their research, they also found that interactive local-based digital e-modules are very effective in improving students' critical thinking skills. The interactivity of e-modules allows students to be actively involved through exploration, discussion, and reflection, not just reading the material. Research by Hwang et al. (2012), shows that contextual and interactive digital learning can increase the effectiveness of critical thinking development. The combination of local potential and interactive e-modules can create

optimal learning conditions for the development of critical thinking in biology learning. Authentic problem-based learning can also increase the effectiveness of critical thinking development and conceptual understanding of students (Bybee, 2013; Makhrus et al., 2025; Pertiwi et al., 2024).

Table 5. Analysis of the effectiveness of local-based e-modules on critical thinking

Author's name	Effectiveness level
Dewi et al. (2017)	Conceptually effective, i.e., there was a significant increase in critical thinking scores through analysis and evaluation.
Syahfitri & Muntahanah (2024)	Improvement in critical thinking skills and dissociation
Pertiwi et al. (2024)	Effective, as evidenced by an increase in problem-solving and inference abilities
Makhrus et al. (2025)	There is also a significant increase in higher-order critical thinking processes.
Nurhidayati et al. (2024)	The Project-Based Learning model based on local potential encourages students to conduct in-depth investigations, analyze environmental issues, and engage in critical reflection, which contributes to improving critical thinking and environmentally friendly behavior.
Aliyah & Widiyatmoko (2022)	Improving students' critical and creative thinking skills through entrepreneurship-based biotechnology e-modules that require decision making, process evaluation, and impact analysis.
Pitorini (2024)	The combination of PBL-based e-modules and Socratic Dialogue significantly improves students' analytical skills, argument evaluation, and logical conclusion drawing.
Suryawati et al. (2024)	Improved critical thinking and self-regulation of students through metacognitive-based e-learning modules that train monitoring and evaluation of thinking processes.
Pitorini (2025)	The development of depth of reasoning, reflective abilities, and the quality of students' scientific arguments during the PBL-based learning process and Socratic dialogue.
Serevina et al. (2022)	A significant increase in students' critical thinking scores through interactive and flexible Android e-modules, even though they are not entirely based on local potential.
Salampessy & Suparman (2020)	Problem-Based Learning-based modules improve critical thinking skills through contextual problem solving, data analysis, and systematic solution evaluation.

RQ3: What Challenges are Faced in the Implementation of E-Modules Based on Local Potential in Biology Learning?

Based on the analysis in Table 6 regarding the challenges in implementing locally-based e-modules in the learning process, there are conceptual, technological, pedagogical, cognitive, and contextual challenges. One of the fundamental challenges identified, as in the study by Dewi et al. (2017), is the lack of systematically structured teaching materials for integrating local potential into the science learning process. Local potential is often still considered as an additional example rather than a main conceptual framework for application in learning. Theoretically, the integration of local context requires teachers to carry out curriculum contextualization, which is learning that can adapt scientific content to the social reality or daily life of students without losing its scientific essence (Barnett & Hodson, 2001).

Research by Syahfitri & Muntahanah (2024) states that although e-modules based on local potential have proven to be effective, the digital literacy gap remains an obstacle to their application or implementation. Not all teachers have the ability to develop or modify digital e-modules independently. In addition, the effectiveness of digital learning is greatly influenced by the technological readiness of teachers and students (Scherer, 2019). Without adequate support and training, locally-based e-modules will likely only be used to a limited extent or may even be unsustainable. Furthermore, issue- or problem-based e-modules pose a challenge in managing students' cognitive responses, which can lead to conceptual confusion (Makhrus et al., 2025). Another challenge for teachers is balancing the authenticity of the local context with the level of difficulty of the basic biological concepts in their application. Another challenge is the adaptation of e-modules based on local potential to the national curriculum. Local potential is specific to a particular region or area, while the curriculum is national and standardized. This requires flexibility in the design of e-modules based on the relevance and needs of each region so as not to deviate from the learning outcomes and objectives. Another challenge is the adaptation of local potential-based e-modules to the national curriculum (Nurhidayati et al., 2024).

Local potential is specific to a particular region or area, while the curriculum is national and standardized. This will require flexibility in the design of e-modules based on the relevance and needs of each region so as not to deviate from the learning outcomes and objectives. Based on an analysis of 11 articles, the challenges of implementing e-modules based on local potential can be found in pedagogical aspects, which require alignment between the curriculum and learning design; cognitive aspects, which require learning loads and heterogeneity of student abilities; access and digital

literacy; and a culture of critical thinking and reflective readiness. However, these challenges are not absolute obstacles, but rather opportunities to develop e-module models that are more adaptive, contextual, and sustainable.

Table 6. Analysis of challenges

Author's name	Challenges found
Dewi et al. (2017)	There are limitations in structured teaching materials and teacher readiness in systematically integrating local potential.
Syahfitri & muntahanah (2024)	There is a gap in digital literacy between teachers and students, as well as limitations in facilities.
Pertiwi et al. (2024)	The complexity of e-module design and the need for high pedagogical and technological competencies
Makhrus et al. (2025)	Difficulties for teachers in implementing cognitive conflicts or issues and adapting local materials into the curriculum
Nurhidayati et al. (2024)	The challenge of aligning projects based on local potential with curriculum outcomes and limited learning time for in-depth investigation and critical reflection.
Aliyah & Widiyatmoko (2022)	The difficulty of integrating the concepts of entrepreneurship, biotechnology, and local context in a balanced manner without overloading students' cognitive load.
Pitorini (2024)	Challenges in familiarizing students with the Socratic dialogue approach, especially in the early stages of learning due to the low culture of questioning and critical argumentation.
Suryawati et al. (2024)	The implementation of metacognitive-based modules requires the readiness of students and lecturers in self-regulated learning and monitoring of thinking processes, which is not yet evenly distributed.
Pitorini (2025)	In qualitative studies, variations in students' abilities to participate in problem-based discussions were found, resulting in uneven effectiveness of critical dialogue across groups.
Serevina et al. (2022)	Limitations in devices, internet access, and differences in students' digital literacy abilities are major obstacles in the use of Android-based e-modules.
Salampessy & Suparman (2020)	Teachers' difficulties in designing truly authentic contextual problems and the need for intensive training to consistently apply PBL.

Conclusion

Based on the results of the Systematic Literature Review (SLR), out of a total of 109 articles identified in the initial stage, eleven articles were selected that met the inclusion criteria and relevantly answered the research question of this study. The synthesis results show that the application of local potential-based e-modules consistently has a positive effect on improving students' critical thinking skills in biology learning. The integration of local contexts into e-modules allows students to relate biological concepts to real phenomena in their surroundings, thereby encouraging higher-level cognitive activities, such as analysis, evaluation, inference, and scientific reasoning. The effectiveness of local potential-based e-modules is proven to be more optimal when designed using student-centered pedagogical approaches, such as problem-based learning, project-based learning, metacognitive approaches, and reflective dialogue, and supported by interactive features that can increase students' cognitive and affective engagement. Thus, e-modules based on local potential not only function as a digital medium for delivering material, but also as a means of meaningful contextual learning in developing critical thinking skills in a sustainable manner. However, the results of the study also show that the implementation of e-modules based on local potential still faces a number of challenges, including limited digital literacy among teachers and students, the complexity of e-module design that requires mastery of pedagogical and technological competencies, and difficulties in aligning local potential with national curriculum requirements. These challenges indicate that the successful implementation of e-modules based on local potential depends not only on the quality of teaching materials, but also on the readiness of human resources and learning system support. Thus, e-modules based on local potential can be seen as a strategic learning innovation in enriching contextual and digital-based biology learning studies. The findings of this SLR are expected to contribute theoretically to the development of local potential-based learning models, as well as provide practical implications for educators and teaching material developers in designing relevant, effective, and sustainable e-modules to improve students' critical thinking skills.

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Author Contributions

Conceptualization, Y.H. and R.; methodology, A. and Y.H.; investigation, writing-preparation of original draft and

visualization, Y.H.; resources, writing-reviewing and editing, Y.H., R., and A.; supervision, R. and A. All authors have read and approved the published version of the manuscript.

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