

Research Article

Cite this article: Makhrus, M., Rahayu, S., Santoso, D., & Annam, S. (2025). Effect of E-Module Based on Sustainable Development Goals (SDGs) with Conceptual Change Model-Cognitive Conflict Approach (CCM-CCA) Integrated with Local Wisdom on Students' Critical Thinking Skills. *Educational Process: International Journal*, 17, e2025399. <https://doi.org/10.22521/edupij.2025.17.399>

Received June 12, 2025

Accepted August 8, 2025

Published Online August 21, 2025

Keywords: CCM-CCA, Critical Thinking, E-module, Local Wisdom, SDGs

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Effect of E-Module Based on Sustainable Development Goals (SDGs) with Conceptual Change Model-Cognitive Conflict Approach (CCM-CCA) Integrated with Local Wisdom on Students' Critical Thinking Skills

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Abstract

Background/purpose. This research aims to analyze the influence and test the effectiveness of using an e-module 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.

Materials/methods. This research employed a quasi-experimental design with a pre-test and a post-test control group. Research subjects were 128 10th-grade students studying measurement material in physics subjects. The research subjects were divided into two groups. The first group was the experimental group (taught using e-modules based on CCM-CCA integrated with local wisdom) with 65 students, and the second group was the control group (taught using a conventional learning model) with 63 students. The research instrument includes a set of descriptive questions to measure critical thinking skills. Data analysis included descriptive and inferential analysis.

Results. To examine the improvement in students' critical thinking skills, an n-gain analysis was conducted, and the influence of the e-modules was tested using an independent t-test. The findings revealed that students in the experimental class demonstrated a greater improvement in critical thinking skills compared to those in the control class. Statistical analysis confirmed a significant difference in post-test performance between the two groups, indicating that the use of e-modules had a positive and meaningful impact on students' critical thinking abilities.

Conclusion. An e-module based on sustainable development goals (SDGs) with a conceptual change model-cognitive conflict approach (CCM-CCA) integrated with local wisdom influences critical thinking skills.

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1. Introduction

The 21st century is an era in which several generations are faced with the era of globalization (Peters-Burton & Stehle, 2019). In the 21st century, human life has experienced fundamental changes that are different from the challenges of previous lives (Van Laar et al., 2020). Significance of skills, the 21st century has become a significant focus of current educational research (Geisinger, 2016). This is caused by the importance of 21st-century skills as preparation for students to face various future challenges (Larson & Miller, 2011) and has a substantial impact on students' lives after they complete their formal education (Kaufman, 2013). The implementation of 21st-century skills is considered to be a must in every process of learning (Dicerbo, 2014; Fry & Seely, 2011; Griffin, 2017; Jang, 2016; Lambert & Gong, 2010; and Sibille et al., 2010).

Some of the challenges in the 21st century include critical thinking skills, problem-solving, communication and collaboration skills, and the ability to use information and communication technology for daily activities (González-Pérez & Ramírez-Montoya, 2022). Critical thinking skills are key skills for students to adapt to the external challenges of the 21st century (Nia et al., 2022; Bilad et al., 2022). This is in line with the fourth goal of the SDGs, namely, promoting quality education. Quality education can be obtained by mastering one of the 21st-century skills, namely critical thinking (Setiawan, 2022).

Critical thinking involves the ability to analyze arguments, identify biases, evaluate evidence, and draw reasoned conclusions. These skills are essential for students in physics, where understanding intricate systems and making data-driven decisions are crucial (Amin et al., 2020; Sadeghi et al., 2020; Aston, 2023; Sapriati et al., 2024; Komalasari et al., 2024; Fauziah et al., 2024; Puger et al., 2024). While several previous studies have explored strategies and models to enhance critical thinking, such as problem-based learning and inquiry-based approaches, few have focused on integrating a conceptual change model combined with cognitive conflict (CCM-CCA) and local wisdom in a digital format. This presents a gap in the literature. Existing e-modules often emphasize content delivery without deliberately stimulating conceptual change or addressing students' misconceptions through cognitive conflict strategies. Moreover, the incorporation of local wisdom as a contextual scaffold in physics learning remains underexplored, despite its potential to connect students' lived experiences with scientific reasoning (Parmin, 2015; Annam et al., 2023).

Students' critical thinking skills in science material are relatively low, with an average of 40.62%. This can be observed when students give opinions on problems/questions raised by the teacher (Hidayanti et al., 2021). Science teachers must provide instructions first so that students can answer the teacher's questions. Students' difficulty in understanding the concept of science is also supported by the lecture method used by teachers and learning media that still refer to textbooks, resulting in science subjects being considered less interesting (Sari et al., 2022). This means students have not achieved a higher level of critical thinking (Zulkifli & Hasyim, 2020). This happened because most practical learning has not been oriented towards the attainment of CT skills (Verawati et al., 2022; Bensley & Murtagh, 2012).

The low critical thinking skills are caused by several factors, namely the unavailability of teaching materials that facilitate the improvement of students' critical thinking skills. Teaching materials in schools still do not support the digitalization of education through the independent curriculum because they are still printed teaching materials. In addition, learning is still teacher-centered, and students have not been able to connect their knowledge with science issues in everyday life. In addition to the importance of 21st-century skills, there are other important things to note. This is the shifting of local cultural values originally from Indonesia, which is a result of globalization where foreign cultural values are growing rapidly in Indonesia (Parmin, 2015; Annam et al., 2023).

Based on the description above, one of the efforts that can be made is by developing teaching materials in the form of e-modules using a model that can facilitate the improvement of critical thinking skills according to the SDGs goals. The learning model used is CCM-CCA (Conceptual Change Model with Cognitive Conflict Approach) and integrated local wisdom. The reality of shifting cultural values has resulted in local cultural values being forgotten. So, it is necessary to make more massive efforts through education so that local wisdom values can be preserved (Parmin, 2015). Several skills, such as critical thinking and problem solving, can be trained by implementing local wisdom in learning (Hunaepi et al., 2020; Annam et al., 2023). Learning using CCM-CCA, assisted by virtual experiments, can improve critical thinking skills (Makhrus et al., 2020). People who think critically are people who can reflect on their knowledge, think rationally and factually, and use relevant information to solve a problem (López et al., 2022).

CCM-CCA provides cognitive conflict stimulation so that it can reduce misconceptions (Makhrus, 2018). The most effective implementation of CCM-CCA involves activities such as diagnostic teaching, where learning is designed to reveal what is thought in relation to existing problems and provide situations or problems that make them think. This activity causes the growth and development of students' critical thinking skills (Makhrus et al., 2014). In addition, CCM-CCA has been proven to have an effect on students' problem-solving abilities (Fitriana et al., 2020). The process of solving a problem requires good critical thinking skills.

The use of learning models is very good when combined with the use of learning media (Muzaki et al., 2022). This is closely related to the use of information and communication technology, which is developing rapidly as an effort to digitize education in the implementation of the independent curriculum. Information and Communication Technology (ICT)-based learning in the world of education cannot be separated from the needs of 21st-century learning, especially in science learning (Setyawan, 2019).

One of the media that can be utilized is teaching materials integrated with technology, such as electronic modules or e-modules. To make it more interesting and easily accessible, e-modules can be uploaded to the Heyzine Flipbook website. Just by dragging, dropping or clicking, we can insert YouTube videos, hyperlinks, animated texts, images, audio, and flash into the flipbook (Manzil et al., 2023). Based on the description above, students' critical thinking skills will be improved through the development of e-modules based on CCM-CCA integrated with local wisdom. So, this research aims to analyze the influence and test the effectiveness of using e-modules in improving students' critical thinking skills.

2. Literature Review

2.1. Sustainable Development Goals (SDGs)

The Sustainable Development Goals (SDGs) are a global framework established by the United Nations in 2015 to address the multidimensional challenges facing humanity. The SDGs consist of 17 goals and 169 interrelated targets, emphasizing the importance of sustainable development. This initiative requires cross-sectoral involvement and collaboration between developed and developing countries in implementing the principles of sustainable development (Leal Filho et al., 2019). Research shows that implementing the SDGs requires the integration of national policies with measurable sustainability indicators and strengthening the capacity of local institutions (Sachs et al., 2021). However, major challenges remain, resulting in delays in achieving some goals (Kroll et al., 2019). Therefore, a systemic approach is needed that takes into account the social, economic, and ecological dimensions simultaneously so that these global development goals can be achieved effectively.

2.2. Conceptual Change Model-Cognitive Conflict Approach (CCM-CCA)

The Conceptual Change Model–Cognitive Conflict Approach (CCM–CCA) is a pedagogical approach designed to address students’ misconceptions by facilitating conceptual change through planned cognitive conflict. This model is rooted in the theory of conceptual change (Posner et al., 1982), which states that a person must experience intellectual discomfort due to a mismatch between prior knowledge and new information acquired. In the CCM–CCA approach, cognitive conflict is used to stimulate a mismatch between students’ prior ideas and actual scientific phenomena, which is then followed by a process of knowledge restructuring (Limón, 2001). CCM–CCA is also in line with constructivist learning theory, because it encourages students to reflect on and rebuild their knowledge through an active process of making sense of the learning experience.

2.3. Local Wisdom

Local wisdom is the accumulation of knowledge, values, norms, and practices that are passed down from generation to generation in a community and have proven to be adaptive to the social, cultural, and ecological environment. Local wisdom is not only a traditional knowledge system, but also reflects community strategies in managing natural resources and maintaining sustainability of life (Geertz, 1983). In the modern context, local wisdom has received attention in multidisciplinary studies because of its strategic role in shaping alternative approaches to sustainable development, disaster mitigation, and environmental conservation (Pretty et al., 2009). Scientific studies also show that the integration of local wisdom into public policy and formal education can strengthen cultural identity and increase the effectiveness of community-based interventions (Adams, 2010).

2.4. Critical Thinking and SDGs

Critical thinking has been widely recognized as a core competency in 21st-century education, particularly in science learning contexts. It enables students to interpret information, evaluate evidence, and construct logical arguments, all of which are crucial for developing scientific literacy. Despite its importance, several studies report that students’ critical thinking skills remain underdeveloped due to the prevalence of teacher-centered instruction, limited use of digital learning resources, and the insufficient application of pedagogical models that actively engage learners in conceptual restructuring. This highlights the need for innovative instructional designs that not only foster critical thinking but also align with broader educational objectives.

One of these broader objectives is the advancement of the United Nations Sustainable Development Goals (SDGs), particularly SDG 4, which emphasizes inclusive and equitable quality education and the promotion of lifelong learning opportunities for all. Achieving SDG 4 entails more than just expanding access to education; it requires a transformation in the quality and nature of learning itself. In this regard, critical thinking plays a pivotal role. It supports transformative learning processes where students are encouraged to question assumptions, explore diverse perspectives, and make informed decisions—skills that are fundamental for navigating complex social, environmental, and ethical issues. As Evans et al. (2018) argue, fostering critical thinking is essential for enabling learners to engage meaningfully with sustainability challenges. Similarly, Sughra et al. (2022) emphasize that curricula in developing countries must be reoriented to explicitly nurture critical thinking as a key step toward realizing the targets of SDGs. Thus, enhancing students’ critical thinking through contextually relevant, well-designed digital materials such as e-modules represents a strategic contribution to both educational quality and sustainable development.

3. Methodology

This research used an approach called experimental research to determine the impact and improvement (O’Dwyer & Bernauer, 2013). The research employed a pre-test and post-test control group design (Johnson & Christensen, 2014; Kumar, 2011).

Experimental research aims to determine, in controlled settings, how different therapies affect other individuals (Brunstein, 2013). This research employed a quasi-experimental design. 128 10th grade students studying measurement material in physics subjects were the research subjects, and research subjects in particular groups had specific objectives. A quasi-experimental design was employed because controlling every relevant variable except a few was impossible. In this research, respondents were divided into two groups. The first group was the experimental group (taught using e-modules based on CCM-CCA integrated with local wisdom) with 65 students, and the second group was the control group (taught using a conventional learning model) with 63 students.

The research commenced with a comprehensive planning and preparation stage. The objective was to design and prepare the CCM-CCA activities and materials. This involved conducting an extensive review of the literature on e-module, CCM-CCA, and critical thinking in physics education to develop relevant and effective activities. Detailed lesson plans, instructional materials, and assessment rubrics were created based on the findings from the literature review and consultations with experts.

The next stage involved the implementation of the CCM-CCA e-module. During this stage, students engaged in various activities including presenting the context of the problem, determining outcomes or positions, exposing beliefs, creating cognitive conflict, accommodating and expanding concepts, solving or testing the problem and evaluating. Reflective sessions were integrated into the program to allow students to assess the strengths and weaknesses of their activities.

Monitoring and assessment were crucial components of this research. Throughout the CCM-CCA activities, students' engagement and skill development were closely monitored by observers. Tutors evaluated student discussions and assignments using detailed rubrics designed for CCM-CCA and critical thinking assessments. These rubrics included indicators for various skills such as presenting the context of the problem, determining outcomes or positions, exposing beliefs, creating cognitive conflict, accommodating and expanding concepts, solving or testing the problem and evaluating (see Tables 1 and 2). The evaluation process aimed to gauge the effectiveness of the CCM-CCA approach in enhancing critical thinking.

Table 1. Indicator and Rubrics of CCM-CCA

Indicators	Assessments Rubrics
Indicator 1: presenting the context of the problem	Students are able to identify problems presented in the given phenomena
Indicator 2: determining outcomes or positions	Students are able to find solutions to problems through the material presented.
Indicator 3: exposing beliefs	Students are able to formulate hypotheses to answer the problems presented.
Indicator 4: creating cognitive conflict	Students are able to design experiments or activities according to hypotheses.
Indicator 5: accommodating and expanding concepts	Students are able to carry out experiments or activities according to the work steps
Indicator 6: solving or testing the problem	Draws conclusions, presents findings/results clearly, and utilizes appropriate scientific references.
Indicator 7: evaluating	Evaluating methodologies, critiquing the processes used, assessing strengths and weaknesses, and developing improvement plans

The final stage of the research involved data analysis. The data collected from student assessments were analyzed to determine the impact of the CCM-CCA e-module on critical thinking skills. Descriptive statistics were calculated to summarize the data. Inferential statistics, specifically regression analysis, were performed to examine the relationship between participation in the CCM-CCA e-module and improvements in critical thinking skills. Table 2 shows the indicators and rubrics of critical thinking skills.

Table 2. Indicator and Rubrics of Critical Thinking Skills

Indicators	Assessments Rubrics
Indicator 1: Basic clarification	• Focusing questions • Analyzing arguments • Asking and answering clarification and/or challenge questions
Indicator 2: Basic decision	• Consider the credibility of the source • Observe and consider the results of observations
Indicator 3: Inference	• Deduce and evaluate the results of deduction • Create and evaluate the factors resulting from consideration
Indicator 4: Further explanation	• Define terms and consider a definition • Identify assumptions
Indicator 5: Reasoning and integration	• Reasoning • Integrating

To find the effect, the independent sample t-test was used. Before carrying out the independent sample t-test, researchers carried out a practical test with a normality test and a homogeneity test. Next, they carried out a hypothesis test with the t-test. Hypotheses in this research contain the null hypothesis and alternative hypotheses. The null hypothesis states that the e-module based on sustainable development goals (SDGs) with the conceptual change model-cognitive conflict approach (CCM-CCA) integrated with local wisdom does not influence critical thinking skills. The alternative hypothesis states that the e-module based on sustainable development goals (SDGs) with the conceptual change model-cognitive conflict approach (CCM-CCA) integrated with local wisdom influences critical thinking skills.

To see the improvement, the N-Gain score was used. Researchers carried out prerequisite tests in the form of normality and homogeneity tests, then looked for the N-Gain value to see whether there was an increase. The N-Gain score was obtained from the posttest score minus the pretest score, the result of which was divided by the ideal score that had been reduced by the pretest score. The N-Gain value categories are as follows: high category if the score is more than 0.7, low category if the score is more than 0.3 and less than 0.7, and low category if the score is less than 0.3. The data collection instruments used include effectiveness instruments in the form of critical thinking ability tests, in the form of descriptive questions.

The results of the validity of the instruments state that the significance value of all instruments is smaller than 0.05, so it can be concluded that all instruments are valid. The reliability results state that the Cronbach's Alpha value for critical thinking ability is 0.688. The Cronbach's Alpha value is more than 0.6, so it can be concluded that the instrument is reliable. Normality data analysis used

the Kolmogorov-Smirnov test, and the homogeneity test used Levene's statistic. The data was analyzed using IBM SPSS 26.

4. Results

(A concise and precise description of the results should be provided)

The results of students' critical thinking abilities were obtained using a test instrument in the form of 5 descriptions. The results of the initial test and final test of students in the experimental class and control class can be seen in the table as follow

Table 3. Pre-Test and Post-Test Scores in the Experimental Class and Control Class

Data	Pre Test		Post Test	
	Experimental Class	Control Class	Experimental Class	Control Class
Amount of Students	65	63	65	63
The Highest Score	45	40	80	75
The Lowest Score	5	5	45	25
Score Average	22.17	23.33	65.33	52.41

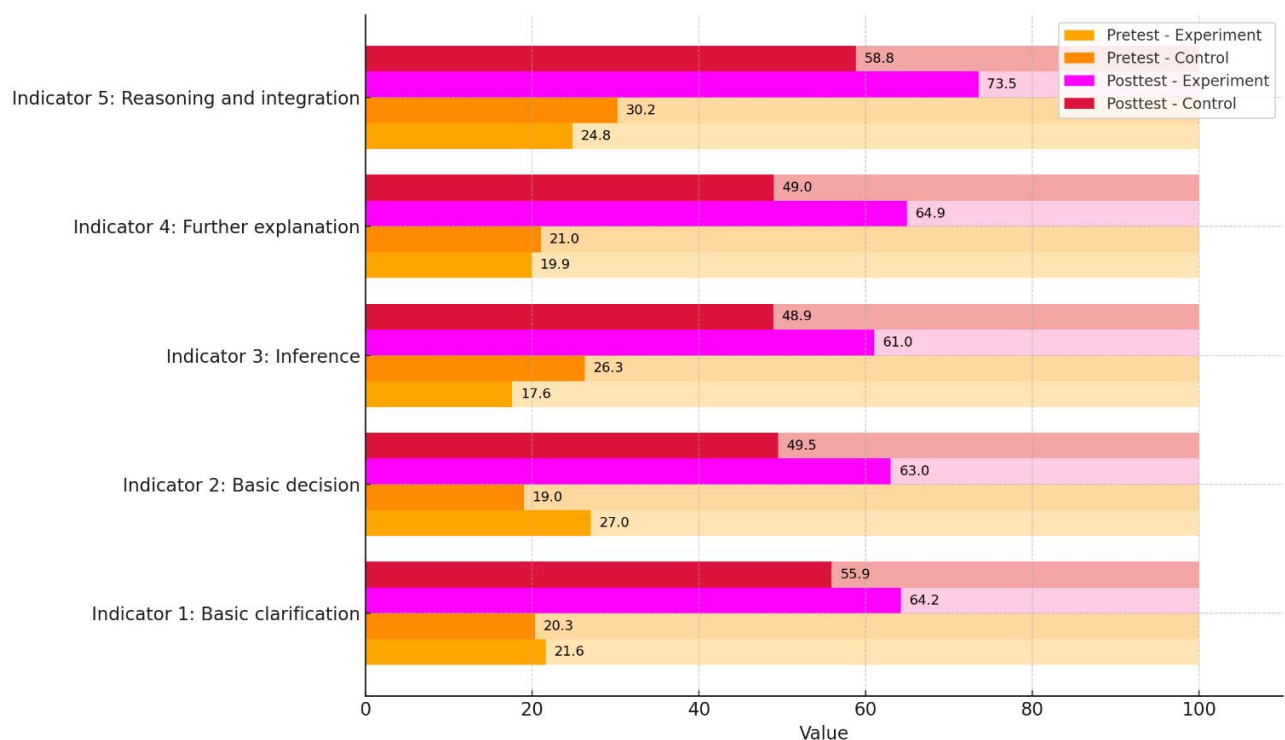


Figure 1. Comparison of Pretest and Posttest Scores Across Five Critical Thinking Indicators

Based on Table 3, there is an average difference in both the initial and final tests of students. The average score of students before being given treatment for the experimental class was 22.17, which was in the very low category and for the control class was 23.33, which was in the very low category. The average score of the students after being given treatment in the form of the CCM-CCA-based e-module for the experimental class was found to be an average score of 65.33, which is in the medium

category. Meanwhile, for the control class that was given conventional method treatment, the average score was 52.41, which was included in the low category.

Figure 1 presents a comparison of pretest and posttest scores on five critical thinking indicators, both for the experimental and control groups. It can be seen that the posttest scores in the experimental group were consistently higher than their pretest scores, reflecting an increase in ability after the treatment. Significant improvements were also seen compared to the control group, which experienced more limited increases. The indicator with the highest increase in the experimental group was Reasoning and Integration, while in the control group, the increase was relatively even but lower overall. The findings indicate that the treatment given to the experimental group was effective in improving students' critical thinking skills across all measured indicators. The average score data is entered into the N-gain formula to obtain results like those in Figure 2.

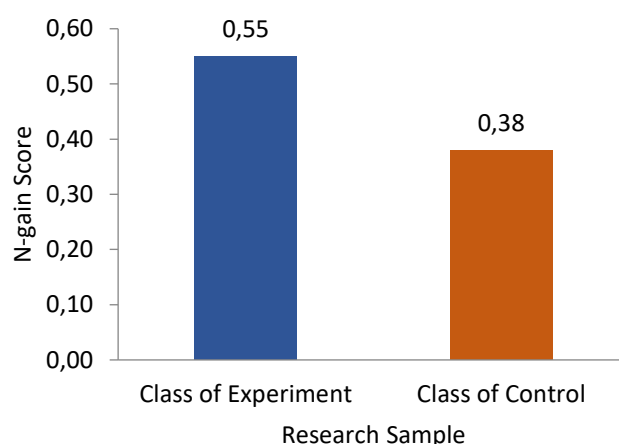


Figure 2. Increase in the Average Score of Students' Critical Thinking Abilities in the Experimental Class and the Control Class

The influence of e-module based on sustainable development goals (SDGs) with conceptual change model-cognitive conflict approach (CCM-CCA) integrated with local wisdom on critical thinking skills can be seen through tests, including the Normality test. The significance value of critical thinking for the experiment class = 0.251 > 0.05, so the data is average. The significance value of critical thinking for class control is 0.180, which is greater than 0.05, indicating that the data is average. Meanwhile, in the homogeneity test, the significance value of critical thinking is 0.471, which is greater than 0.05, indicating that the data variance is homogeneous. In hypothesis testing, only post-test data is used. The results can be seen in the following table:

Table 4. Independent Samples Test

		Levene's Test for Equality of Variances	t-test for Equality of Means
		Sig.	Sig. (2-tailed)
Critical thinking	Equal variances assumed	.471	.000

Based on Table 4, the sig. (2-tailed) value is 0.000 < 0.05, so H_0 is rejected, and H_1 is accepted. This means that there is a significant difference between the post-test averages of the experimental class and the control class. So, an e-module based on sustainable development goals (SDGs) with a conceptual change model-cognitive conflict approach (CCM-CCA) integrated with local wisdom influences critical thinking skills.

Based on Table 3, it can be seen that the average initial test score for students' critical thinking abilities in the experimental class taught using the CCM-CCA learning model was 22.17 which was included in the very low category and the control class taught using the conventional learning model was 23.33, which is included in the very low category. The critical thinking ability category in both classes is at the lowest level of thinking. The average score of the initial critical thinking ability test is used as a benchmark to see the increase in students' critical thinking abilities in the final test results after being given treatment in the form of the CCM-CCA model.

The average final test score for the experimental class taught using the CCM-CCA learning model was 65.33, which was included in the low category, and the control class taught using the conventional learning model was 52.41, which was included in the very low category. Both classes experienced an increase in the average value of critical thinking abilities, this shows that the application of the CCM-CCA model has an effect on students' critical thinking abilities. The experimental class taught using the CCM-CCA learning model experienced much better improvement when compared to the control class.

These results can occur because this model not only has to remember a number of facts, but learning is a process of being active and thinking which starts from the orientation phase (introducing the problem), idea elicitation (questioning students' ideas), idea restructuring (explaining related ideas), idea application (applying ideas in discussion), and change review (summarizing conceptual changes that occur). Each phase contained in the CCM-CCA model provides opportunities for students to participate actively with the aim of training students' abilities to develop critical thinking skills before making a decision. This model is also very appropriate to use for material on optical instruments because students still have unstable concepts or misconceptions, so this model will change students' initial inaccurate concepts into existing scientific concepts.

5. Discussion

The renewable energy material in this e-module includes: the definition and characteristics of renewable energy, as well as its differences from non-renewable energy; types of renewable energy such as solar energy: utilization of solar panels and the working principle of photovoltaic cells, wind energy: conversion of kinetic energy into electricity through turbines, hydro energy: utilization of river flow and dams (hydroelectric power plants) as sources of electricity, biomass energy: conversion of organic waste into heat and electricity (e.g., biogas), geothermal energy: utilization of heat from within the Earth through geothermal power plants; the benefits, challenges, and applications of renewable energy in daily life, as well as the ecological and social impacts of energy use and its relation to global issues such as climate change and the energy crisis.

The e-module is developed based on the principles of the SDGs, notably SDG 7 (Affordable and Clean Energy), SDG 13 (Climate Action), and SDG 4 (Quality Education), and integrates local wisdom, such as: the use of traditional water wheels in mountainous areas as a simple form of hydropower, making biomass stoves from agricultural waste, energy-saving traditions in local cultures, and stories or practices from local communities that demonstrate environmental awareness.

The CCM-CCA (Conceptual Change Model – Cognitive Conflict Approach) approach in the e-module is designed to create conceptual change through cognitive conflict strategies. Students are invited to explore their initial conceptions (e.g., that energy can only be generated from fossil fuels), and are then confronted with scientific facts, interactive animations, digital simulations, local case studies, and real data that challenge those misconceptions and guide them toward scientific understanding.

This learning process, based on cognitive conflict, develops critical thinking skills, such as identifying and formulating energy-related problems, analyzing cause-and-effect relationships

between energy choices and their impacts, evaluating various alternative solutions based on scientific evidence and local contexts, drawing conclusions, and making environmentally and socially responsible decisions. Thus, the implementation of an SDG-based e-module with the CCM-CCA approach, integrated with local wisdom in the renewable energy material for grade 10, has a positive impact in shaping students who are critical, reflective, scientifically literate, and concerned about sustainable development (Figure 3).



Figure 3. Sample of the e-Module Based on Local Wisdom

The most effective implementation of the CCM-CCA model, according to Makhrus et al. (2014), is by involving activities such as diagnostic teaching, where learning is designed to express what people think in relation to existing problems and provide situations or problems that make them think. This activity causes the growth and development of students' critical thinking abilities. Udayani et al. (2014) stated that critical thinking skills can develop if students are always faced with a problem. Learning that demands optimal involvement in the learning process can improve critical thinking skills. In addition to learning factors with CCM-CCA, increased critical thinking skills are also caused by the use of interactive e-modules in learning.

These results are consistent with prior research demonstrating that conceptual change strategies effectively support the development of critical thinking and scientific understanding. A recent meta-analysis by Pacacı (2024) confirmed that instructional approaches designed around conceptual change significantly enhance learning outcomes in science education. Moreover, Limón's foundational work on cognitive conflict emphasizes its role as a catalyst for conceptual restructuring, particularly when contradictory information is used to challenge learners' preconceptions. Unlike many earlier studies that relied on abstract or decontextualized examples, our study extends the theoretical framework by integrating local wisdom and SDG-related contexts into the cognitive conflict design. This dual contextualization not only reinforces scientific concepts but also embeds cultural and sustainability dimensions, enriching students' engagement and reflection. Thus, the present findings support and broaden the theoretical proposition that meaningful conflict—especially when grounded in learners' environmental and cultural realities—fosters deeper conceptual change and higher-order thinking.

Electronic modules (e-modules) are teaching materials that are designed in a structured manner based on the curriculum and arranged in a certain time unit and packaged using electronic devices

such as computers or androids. E-modules integrate formative tests in the form of online tests. E-modules are digital media that have the advantages of being easy to carry anywhere, effective and able to train students' independence in understanding a material. Other advantages are its interactive nature, ease of navigation, and the ability to include images, audio, video, and animation. Additionally, there is a formative test/quiz menu with automatic feedback. Electronic learning modules that are integrated with animations, images, and learning videos are expected to present real experiences for students, so that students can be stimulated to apply their knowledge to the material. (Clark & Mayer, 2016; Lestari & Parmiti, 2020; Cahyanto et al., 2022; Yolanda, 2021; Fatimah et al., 2020).

Pictures, videos, animations, and simulations can help students learn concepts related to heat and temperature. The video that was presented encourages students to understand the discussion described in the e-module. The number of images supports real understanding, and with the simulation, students can gain hands-on experience. Based on the results, students showed a high level of interest, and it was easier to understand the concept with interactive e-module presentations. The effectiveness of the e-module was supported by the evaluation tools presented. Evaluation was used to measure students' critical thinking skills. Evaluation was arranged based on the material presented. The advantages of the e-module being developed were in the material that was widely discussed with real-life concepts, which can be applied in high school to create learning companions. Especially for students who spend a lot of time on their cellphones. It is in line with previous studies about the effectiveness of an e-module at teaching novice learners critical thinking skills, stating that the e-module was helpful in starting new material as a learning tool, because it has flexibility for students to re-learn previous materials while they learn new materials. The use of e-modules can also engage the students by its interactive features (Koth et al., 2021; Serevina et al., 2022; Asrizal et al., 2023; Ariyanti & Bakti, 2024; Putri & Syafriani, 2020; Mahmudah et al., 2022).

So that with this media, it can improve students' critical thinking skills (Linda, 2018). The E-Module in this research can improve the students' critical thinking skills in giving a simple explanation, building basic skills, concluding (inference), providing further explanation, and developing strategies and tactics.

E-modules used in learning are also integrated with local wisdom. Local wisdom integrated into this study is the volume measurement method that is a tradition in the Sasak Tribe, Lombok, namely the grip method. In the grip method, the volume of the object being measured is determined based on the number of objects that can be grasped. The number of objects that can be grasped then becomes the standard unit of measurement for the volume of the object. In the grip method, the smallest unit of volume measurement is one handful which in the local language of the Sasak Tribe is termed *Sekenjau*, *Sebuntut*, *Sekepal*, or *Sepesel* (Hardiani & Putrawangsa, 2019).

Overall, this study shows that learning by using teaching materials with local wisdom insight can significantly improve students' critical thinking skills. This effect is because learning by presenting a real environment in the classroom has the potential to help students learn the core of the concepts being studied, as well as being a bridge to support student activity during the learning process (Fahmi et al., 2019; Irhasyuarna et al., 2022; Kusasi et al., 2021). Science learning materials are more easily accepted by students using local wisdom-based learning resources that are integrated with critical thinking skills (Fitriani et al., 2022; Musliha et al., 2022; Nurlita et al., 2021).

The contribution of this research to education, especially science education, is to provide solutions and information to academics to improve 4C skills, particularly in critical thinking. This research contributes to providing innovation in teaching materials that are compiled into e-modules with an active learning model (CCM-CCA) integrated with local wisdom, proven to improve and influence critical thinking skills. Learning innovation in research is one of the efforts to meet the SDGs

goals, namely quality education. In further research, it is recommended to create other learning innovations to improve other 4C skills such as communication, collaboration, and creative thinking. This is very necessary because 4C skills are essential for students in the 21st century.

6. Conclusion

The research shows an e-module based on sustainable development goals (SDGs) with a conceptual change model-cognitive conflict approach (CCM-CCA) that incorporates local wisdom, thereby improving students' critical thinking skills. The impact of this research can provide solutions and information to academics to improve 4C skills, especially critical thinking skills, through e-modules with an active learning model (CCM-CCA) integrated with local wisdom.

7. Suggestion

Educators and developers of learning media consider the use of e-modules based on Sustainable Development Goals (SDGs) combined with the Conceptual Change Model-Cognitive Conflict Approach (CCM-CCA) and local wisdom as an active learning strategy to improve students' critical thinking skills. Educational institutions need to provide training and technical support to teachers so that they can design and implement such e-modules effectively in various subjects. In addition, further research can be directed to test the effectiveness of this approach on other 4C skills, such as communication, collaboration, and creativity.

Declarations

Author Contributions. Muh. Makhrus: Conceptualization; Writing – original draft, review, and editing; Methodology; Validation; Coordination of research design; Supervision; Resources. Satutik Rahayu: Instructional material development; Validation of learning instruments; Observation and supervision during implementation; Methodology; Validation; Project administration. Didik Santoso: Learning process observation; Support in instructional design; Contribution to analysis discussion; Investigation; Validation of instruments; Formal analysis. Syarful Annam: Data curation; Formatting and final preparation of the manuscript; Visualization. All authors have read and approved the published on the final version of the article.

Conflicts of Interest. The authors declare no conflict of interest.

Funding. Not applicable

Ethical Approval. The research has obtained ethical approval according to applicable procedures. The research was conducted involving human subjects (students), but it will not cause physical or psychological harm to participants, and the privacy of the subjects is kept confidential. The individual in Figure 3 has received permission from the individual to be displayed, because the individual is part of the product of the learning development that has been carried out in accordance with research procedures.

Data Availability Statement. The data that support the findings in this study are available from the corresponding author. Due to ethical and confidentiality considerations regarding the involvement of human participants, the raw data cannot be shared publicly.

Acknowledgments. The authors would like to express their sincere gratitude to the University of Mataram for the support and facilities provided during the research process. The availability of learning laboratories, digital resources, and administrative assistance greatly contributed to the successful implementation of this study.

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