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A Cognitive Conflict-Based E-Module Framework: A Deep Learning Approach to Momentum and Impulse Based on Preliminary Research

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ABSTRACT

The educational challenges of the 21st century demand mastery of critical thinking skills as the primary means for students to adapt to global complexities; however, the reality in schools shows that student achievement remains at a very low level. This study aims to comprehensively describe the results of preliminary research as the primary foundation for designing a physics e-module framework that integrates the cognitive conflict model and the deep learning approach in the topics of Momentum and Impulse. The research method applied is the Development method using the Plomp model, which focuses on the preliminary research phase covering needs analysis, curriculum, literature, and student characteristics. Instrumen pengumpulan data meliputi pedoman wawancara terstruktur untuk guru, lembar analisis bahan ajar, angket observasi kebutuhan peserta didik, serta instrumen tes kemampuan berpikir kritis yang telah divalidasi untuk siswa kelas XI Fase F di SMAN 2 Padang. Hasil analisis data menunjukkan bahwa rata-rata kemampuan berpikir kritis siswa hanya mencapai 43,16% dan bahan ajar yang tersedia saat ini belum memfasilitasi proses rekonstruksi konsep secara mendalam maupun stimulasi berpikir tingkat tinggi secara mandiri. Sebagai solusi inovatif, dirancang sebuah framework e-modul website melalui platform Google Sites yang mengintegrasikan sintaks Model Pembelajaran Berbasis Konflik Kognitif (PbKK) dan tiga pilar utama pembelajaran mendalam (deep learning) yaitu mindful, meaningful, dan joyful. Desain framework e-modul ini dikonstruksi secara sistematis untuk memfasilitasi peserta didik dalam mengatasi miskonsepsi serta melatih proses kognitif tingkat tinggi melalui fitur interaktif seperti video fenomena anomali, simulasi virtual laboratory menggunakan PhET, dan aktivitas refleksi metakognitif.

Keywords :E-module, Cognitive Conflict, Deep Learning, Critical Thinking, Momentum and Impulse

I. INTRODUCTION

The rapid advancement of science and technology in the 21st century has brought about a fundamental transformation in educational paradigms worldwide, including in Indonesia, which is currently implementing the Merdeka Curriculum on a massive scale across various levels of education. The Indonesian nation is now required to continuously improve the quality of its human resources in order to remain competitive amid the dynamic and often unpredictable currents of globalization [1], [2]. In the context of modern education, there are four essential skills that every student must possess to survive and contribute significantly: critical thinking, creativity, communication, and collaboration—collectively known as the 4C skills [1], [3], [4]. These skills are no longer merely academic supplements but have become key indicators of the education system’s success in equipping graduates with the capacity to adapt to rapid technological and economic changes. Science education, particularly in the field of physics, plays a strategic role in fostering systematic, logical, and analytical thinking in students through the rigorous application of the scientific method in every instructional process. Therefore, the current national education curriculum must be able to consistently integrate the development of higher-order thinking skills into every classroom learning activity so that students do not merely become passive memorizers of information that is irrelevant to the needs of the times [4], [5].

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Critical thinking is specifically defined as a rational, reflective thought process used to determine what one should believe or do based on valid evidence and reasoning [5], [6]. Essentially, critical thinking is understood as a cognitive process that involves the ability to interpret, analyze, evaluate, and draw conclusions in order to make rational and objective decisions[6] . This ability encompasses various crucial cognitive dimensions, such as the ability to analyze arguments, objectively evaluate evidence, interpret data, and make decisions based on accurate conclusions [6], [7]. Individuals with strong critical thinking skills tend to be more independent and solution-oriented when solving complex problems, both in academic contexts at school and when facing future professional challenges [4], [8]. However, empirical evidence in the field indicates that the development of these skills is often hindered by the use of conventional teaching methods that remain dominated by one-way lectures from teachers to students in a passive manner [4]. This situation results in students' intellectual potential and cognitive structures not being fully developed during formal education, even though schools should serve as the primary environment for fostering critical thinking among Indonesia's youth through various challenging exploratory activities [6], [9]. This is exacerbated by students' low interest in reading science materials, which are perceived as rigid and difficult to apply functionally in real-life contexts.

Physics, as a scientific discipline, possesses unique characteristics that hold great potential for developing critical thinking skills through mathematical modeling and the empirical observation of natural phenomena [3], [10]. Physics education requires students to be able to connect various visually observable natural phenomena with abstract concepts that are logical, consistent, and physically measurable [11], [12]. Through a structured scientific investigation process, students are taught to formulate hypotheses, gather evidence through virtual and real experiments, and draw conclusions based on universally established scientific principles. These scientific process skills are fully aligned with the vision of the Merdeka Curriculum in shaping the profile of a Pancasila-based learner who possesses critical thinking and strong analytical skills regarding various physical information in their environment [1]. However, in reality, physics learning in schools is often perceived by students merely as a collection of difficult, abstract, and boring mathematical formulas due to the lack of connection between the material and the contextual realities students experience daily [9]. This phenomenon is often referred to as surface learning, where students only scratch the surface of concepts without deeply understanding the underlying physical essence.

The topic of momentum and impulse is one of the most fundamental and crucial subjects at the high school level, requiring students to have a deep conceptual understanding so that they can apply it to various analyses of transportation technology and natural phenomena [9]. Students are expected to be able to interpret the relationship between impulse, contact time, and changes in momentum in various physical events such as vehicle collisions or the working principles of rocket launches [9]. However, field data consistently shows that many students have significant misconceptions in understanding the law of conservation of momentum because the subject matter is considered too abstract and sometimes contradicts their everyday intuition. Difficulties in understanding this basic concept lead to low learning motivation and low student achievement in this subject at the high school level [9]. Furthermore, the limited availability of laboratory equipment in school labs to demonstrate collision events that occur in an extremely short time often confines learning to the mere derivation of formulas. Therefore, a breakthrough is needed in innovative teaching strategies capable of visualizing these physical phenomena to make them more intuitively understandable through the use of currently developing digital technology [12], [13].

The availability of high-quality instructional materials in schools plays a vital role in addressing the challenges of contemporary physics education, which education practitioners must urgently and systematically address [2]. Preliminary observations indicate that most of the printed instructional materials currently used in schools remain highly procedural and fail to provide adequate stimulation to actively foster students' critical thinking skills. The presentation of teaching materials, dominated by dense text and mathematical formulas without the support of interactive multimedia, makes it difficult for students to visualize physical phenomena that occur dynamically and rapidly [2], [14]. Furthermore, these teaching materials have not been intentionally designed to trigger the cognitive conflicts necessary as catalysts for improving students' mental structures and permanently eliminating their misconceptions [15], [16]. Without substantive innovation in the development of teaching materials, the gap between 21st-century competency requirements and the reality of students' actual abilities in the field will widen further, posing a serious threat to the quality of national education [15]. Digital teaching materials responsive to students' needs are the key to bridging this competency gap in this fast-paced era of the Fourth Industrial Revolution.

As an innovative solution to these issues, the development of digital learning media in the form of e-modules has become an urgent necessity for improving students' science literacy and independent learning skills in the digital age [5]. E-modules offer a high degree of flexibility in access as well as the integration of various interactive multimedia features that are not available in conventional print-based instructional materials [13][14]. The integration of the Cognitive Conflict-Based Learning Model (PbKK) into e-module design aims to remediate students' misconceptions by systematically presenting anomalous phenomena that challenge their initial cognitive structures [15], [16]. Additionally, the deep learning approach through the pillars of mindful, meaningful, and joyful learning will deeply strengthen students' emotional and cognitive engagement in understanding the essence of complex physics material [7], [17]. The website-based e-module design using the Google Sites platform is expected to serve as an effective tool in transforming students' learning methods in an increasingly competitive digital era [18], [19]. This article aims to provide a comprehensive description of the results of preliminary research as the primary foundation for designing a physics e-module framework that integrates the cognitive conflict model and the deep learning approach to the topics of momentum and impulse.

II. METHOD

This study employs the Development method, adopting Plomp's model development procedure—which is highly systematic, measurable, and focused-to produce high-quality educational products [3], [15]. This development process is carried out systematically through measurable stages to produce instructional materials that are valid and scientifically sound [20]. The Plomp model was selected because it features clearly defined stages for producing educational products with proven levels of validity, practicality, and effectiveness when implemented in real-world settings. The discussion in this article focuses in depth on the first phase of the Plomp model, namely preliminary research, which aims to objectively identify real-world problems in the field through various initial data collection instruments [3], [15], [21]. This stage serves as a critical foundation for researchers in formulating product development criteria to ensure they are well-targeted and aligned with the characteristics, learning styles, and specific needs of high school students. A comprehensive needs analysis at this stage ensures that the resulting e-module is truly capable of addressing the learning challenges faced by teachers and students regarding the topics of momentum and impulse.

This initial research phase encompasses four main activities that are intrinsically interconnected: a field needs analysis, a theoretical literature review, a curriculum analysis, and a detailed analysis of student characteristics [3]. The researcher conducted direct observations of the digital infrastructure available at SMAN 2 Padang to ensure the technical feasibility of using Google Sites technology in both classroom and self-directed learning processes [18], [22]. Additionally, an in-depth review was conducted of curriculum documents, particularly the Learning Outcomes (LO) for Phase F physics material in the Merdeka Curriculum, which demands very high standards of critical thinking competencies from high school students. A literature review was conducted to strengthen the theoretical foundation regarding the integration of the cognitive conflict model with digital media as an effective strategy for systematically and permanently correcting science misconceptions [15], [16]. All information obtained at this stage was converted into a primary database for formulating e-module design specifications aligned with 21st-century educational competency requirements that demand a high level of independent learning [23].

The research subjects in this preliminary research phase included 30 eleventh-grade students in Class F at SMAN 2 Padang, as well as two senior physics teachers who served as the primary informants for the instructional needs interviews. The research location was selected based on the school's characteristics: it already possessed adequate internet infrastructure, but its use had not yet been optimized for interactive multimedia content capable of stimulating students' interest in learning [14]. The instruments used in data collection included a structured interview guide for teachers, a questionnaire for analyzing instructional material needs for students, and a critical thinking test instrument that had been validated by experts prior to field use [9], [11]. All collected data were then classified based on key themes relevant to the objective of developing the website-based interactive e-module product. The researchers also analyzed potential technical obstacles that students might face when accessing the modules independently to ensure inclusive accessibility of the material for all students without exception through the various digital devices they own (smartphones, laptops, tablets).

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III. RESULTS AND DISCUSSION

1) Analysis of Critical Thinking Skills

The results of the critical thinking skills test conducted during the preliminary research phase at SMAN 2 Padang indicate that students' performance on the topics of Momentum and Impulse falls into the very low category and requires serious attention from educators. Based on the collected statistical data, the average overall student score reached only 43.16% of the maximum score expected by the competency standards at this high school [9], [24]. This concerning situation demonstrates significant barriers in students' reasoning processes when facing physics problems that require in-depth independent analysis to draw rational scientific conclusions. This low proficiency stems from a learning habit that focuses solely on solving numerical problems through rote memorization of formulas without substantively understanding the underlying physical logic of the concept of momentum [9]. This is a critical issue because critical thinking skills are mandatory competencies that must be developed within a modern curriculum oriented toward fostering students' independent thinking in the highly competitive global information age.

A more in-depth analysis of each indicator reveals that the "elementary clarification" aspect—or the provision of simple explanations—had the lowest percentage, reaching only 34.16%. The low score on this indicator suggests that students still struggle to identify basic arguments related to physical phenomena occurring in their immediate surroundings [4], [5]. The importance of critical thinking skills in student learning must be a primary concern for all educational practitioners in schools to ensure that national science literacy improves significantly [4]. Without a strong foundation in providing basic explanations, students will hit a dead end at more complex stages of thinking, such as making inferences and critically evaluating the physical experimental data presented in the questions. These findings provide a very strong empirical basis for researchers to design learning activities that demand sharper analysis within the framework of an innovative e-module designed to gradually and systematically enhance students' reasoning abilities through the reconstruction of correct concepts in accordance with the scientific principles of physics. The percentage details for each indicator are presented in Table 1.

Table 1. Percentage of students' critical thinking skills

Indicator	Percentage (100%)
Elementary Clarification	34,16%
Basic Support	40%
Inference	45%
Advanced Clarification	50%
Strategies and Tacticts	46,67%
On average	43,16%

2) Analysis of Instructional Materials Needs and Field Challenges

In-depth interviews with physics teachers revealed that reliance on conventional printed textbooks remains very high, even though schools have adequate digital technology facilities available for both teachers and students. Teachers acknowledged that the topics of momentum and impulse are difficult to teach using only traditional lecture methods due to the lack of visual aids capable of realistically depicting the extremely rapid collisions that occur in the classroom. The instructional materials currently in use do not include activities designed to intentionally trigger cognitive conflict phenomena to comprehensively improve students' mental structures regarding entrenched scientific misconceptions [15], [16]. Consequently, students' understanding often remains rooted in initial misconceptions even after the learning material has been taught procedurally by teachers through various routine and tedious practice problems. A digital transition medium is needed that can dynamically visualize impulsive force interactions so that physics concepts become more meaningful and concrete for students in their real lives [14]. The shift toward e-learning is no longer an option but a necessity to address students' aspirations for more visual and interactive learning in the post-pandemic era.

An analysis of students' learning preferences shows that 85% of respondents found it easier to understand physics material when supplemented with visually engaging videos and interactive animations [14]. Students stated that the use of videos in physics learning can significantly enhance their learning experience because it clarifies abstract concepts that are difficult to visualize in static textbook illustrations [14]. The availability of the internet and the ownership of personal digital devices by nearly all students represent a significant resource that has not yet been fully leveraged for progressive instructional purposes in secondary schools. Most students find conventional modules—dominated by complex mathematical formulas without strong contextual explanations relevant to their daily lives in their respective regions—boring. Therefore, the development of web-based e-modules rich in interactive multimedia content is a solution that aligns perfectly with the active learning styles of today's digital native generation [13], [14], [25]. Adequate school infrastructure support, such as stable WiFi access, must be optimized to support a self-directed learning model backed by robust digital resources to continuously improve students' technological literacy in order to face the increasingly complex and competitive educational challenges of the 21st century.

3) Design Characteristics of the Proposed E-Module

The e-module design developed using the Google Sites platform has unique characteristics that combine the pedagogical strengths of PbKK with a deep learning approach that is highly effective from an instructional standpoint. The Google Sites platform was chosen for its ease of access across devices (PCs, laptops, smartphones) without requiring the installation of additional applications that burden students' device memory [18]. The navigation structure within the e-module is designed intuitively so that students can follow each phase of learning through a systematic flow without technical confusion while exploring the material independently. Interactive multimedia elements are strategically placed in sections requiring the visualization of physical phenomena that are difficult to explain using only static images in the standard curriculum textbooks. The primary focus of this design is to create an interactive self-directed learning environment centered on students' active cognitive engagement in constructing meaningful new knowledge for their real lives through dynamic visualizations and empirical data from scientifically accurate virtual simulations.

Table 2. Integration of PbKK Model Syntax and Deep Learning in the E-Module Structure

Phase PbKK	Deep Learning	Activity Details in the E-Module
Phase 1 : Preconception Activation	Mindful Learning	Students complete an interactive pre-concept quiz that brings their initial ideas about the material to the surface in a conscious and focused manner
Phase 2 : The Presentation of Cognitive Conflict	Mindful Learning dan Joyful Learning	Showing videos of anomalous phenomena that contradict students' initial understanding to spark deep intellectual conflict.
Phase 3 : Concepts and Equations	Meaningful Learning	The Virtual Lab activity uses PhET simulations to demonstrate the law of conservation of momentum in a self-guided and logical manner.
Phase 4 : Reflection and Evaluation	Mindful dan Joyful Learning	Metacognitive reflection and completion of an interactive assessment quiz (Quizizz) that provides instant feedback.

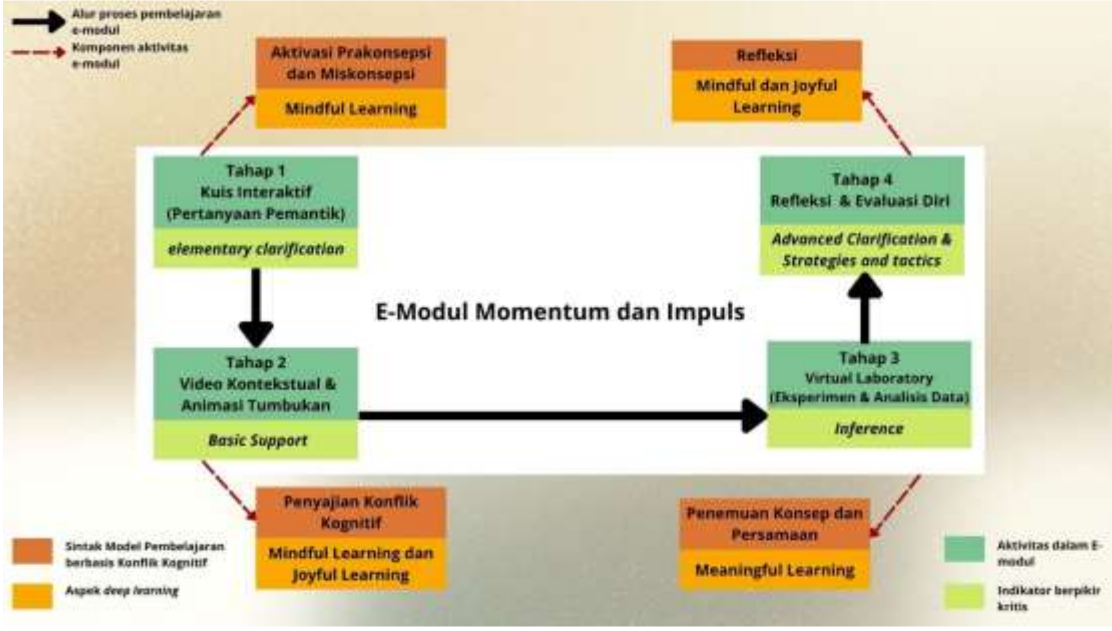

Fig. 1. A framework for e-modules based on cognitive conflict and deep learning

The design of this interactive e-module framework was systematically developed to address students' low critical thinking skills in understanding physics concepts [12], [26]. In the first stage, the e-module presents an interactive quiz to activate preconceptions and identify misconceptions through the Mindful Learning approach to trigger the critical thinking indicator Elementary Clarification [16], [26]. Next, in the second stage, the presentation of cognitive conflict phenomena through contextual videos and collision animations is used to trigger intellectual discomfort that encourages students to seek Basic Support in evaluating their understanding through a Mindful and Joyful Learning environment [16], [26]. Entering the third stage, students are guided to discover concepts and equations through a Virtual Laboratory to build meaningful understanding (Meaningful Learning), where students are trained to achieve the Inference indicator by logically drawing scientific conclusions from experimental data [12], [26]. Finally, in the fourth stage, the reflection and self-evaluation phase is facilitated through the Mindful and Joyful Learning approach to reinforce the Advanced Clarification indicators as well as strategies and tactics in problem-solving [26]. Overall, this framework integrates the functions of assessment for, as, and of learning to create a deep learning experience centered on the student in the digital age [26].

The deep learning approach integrated into the module encompasses three main pillars: mindful, meaningful, and joyful learning, which are interrelated in students' higher-order cognitive processes [7]. The mindful pillar is realized through the use of prompting questions that stimulate students' full awareness of their learning objectives without rigid, externally imposed instructional pressure [7]. The meaningful pillar is applied by linking physics material to real-life contexts and local wisdom, such as in the analysis of the momentum of the traditional Talempong musical instrument, which is familiar to students' daily culture in West Sumatra [27]. Meanwhile, the joyful pillar is achieved through an aesthetically pleasing interface, interactive simulations resembling games (gamification elements), and the provision of instant positive feedback to motivate students to continue exploring actively without excessive boredom. Optimizing the development of this innovative deep learning-based module is crucial for enhancing students' cognitive competencies and long-term memory retention of complex physics material that intellectually challenges them during their school years [3], [7]. The strength of this e-module lies in its ability to present material in a nonlinear manner, allowing students who grasp concepts more quickly to move on to the next challenge, while those who need assistance can replay simulation videos at their leisure until they achieve a comprehensive and deep mastery of the concepts-equipping them with the competencies needed for a bright future that contributes to the nation's progress.

(a)

(b)

(c)

Fig. 2. (a) Visualization (welcome page) of the Physics e-module for high schools (SMA/MA) Phase F (b) Illustration of the concept of momentum in a Newtonian pendulum and representation of the impulse phenomenon in vehicle collisions. (c) Cognitive conflict learning models and deep learning approaches in Physics instruction

Indicators of critical thinking skills, such as analysis, evaluation, and inference, are primarily facilitated during the concept discovery stage and through metacognitive reflection in the e-module, so that students are trained gradually and systematically to engage in higher-order thinking independently. Students are trained to independently connect various physical variables using data obtained from the results of virtual experiments they conduct themselves through the PhET interactive simulation [8]lation [8]. The validity and practicality of such digital products are key to success in effectively and efficiently supporting the achievement of learning objectives in schools for teachers and students in a future filled with global challenges [18]. Through a structured design supported by robust theory, students are expected to develop sharper critical reasoning skills compared to traditional, monotonous learning that relies solely on procedural memorization without deep physical meaning for them. Students’ active engagement in resolving cognitive conflicts will strengthen their mastery of physics concepts in a comprehensive, meaningful, and lasting way, embedding them permanently and deeply within their cognitive structures—a foundation for their future intellectual growth as Indonesia advances on the competitive and dynamic international stage.

4) An In-Depth Discussion of Students' Critical Thinking Skills

The results of the study indicate that students’ critical thinking skills regarding the concepts of momentum and impulse fall into the very low category, with an average score of 43.16%. This indicates that students have not yet been able to optimize higher-order thinking processes to comprehensively understand physics concepts. These low scores not only reflect weaknesses in students’ cognitive abilities but also indicate limitations in instructional design that has not fully supported the systematic development of critical thinking skills [4], [5].

Upon further analysis based on the indicators, it is evident that the “elementary clarification” indicator has the lowest score. This suggests that students still struggle to identify fundamental problems and explain physical phenomena in a simple yet meaningful way. This situation indicates that the ongoing learning process has not provided students with sufficient opportunities to actively construct prior knowledge. In fact, the ability to provide basic explanations is the primary foundation for developing other higher-order thinking skills such as inference and evaluation [5], [6].

In addition, the indicators for inference and strategies and tactics also showed relatively low scores. This suggests that students are not yet accustomed to drawing conclusions based on data or devising logical problem-solving strategies. This lack of proficiency may be attributed to the prevalence of instruction focused on solving routine problems, which has led students to rely more on mechanical patterns than on analytical reasoning [4], [8].

These findings are consistent with theoretical studies indicating that conventional physics instruction, which emphasizes the memorization of formulas and problem-solving procedures, tends to be ineffective in developing students' critical thinking skills. Without stimuli that challenge their cognitive structures, students are not motivated to engage in reflection and evaluation of their own understanding [6], [9]. Therefore, learning strategies are needed that can facilitate students' active engagement in the process of knowledge construction

5) The Role of Cognitive Conflict in Addressing Misconceptions

The current low level of critical thinking skills among students in Indonesia is a serious concern, as the 2022 PISA results show that Indonesia ranks 69th out of 81 countries [26]. This indicates obstacles in students' reasoning processes when faced with physical phenomena that require in-depth independent analysis [26]. One relevant approach to addressing this issue is the cognitive conflict-based learning model (PbKK) [28]. Cognitive conflict occurs when students are confronted with situations that contradict their initial understanding or preconceptions, thereby creating a cognitive imbalance that drives conceptual change [29]. The application of cognitive conflict strategies in e-modules has proven to be crucial, particularly in abstract physics concepts, to encourage students to revise their understanding toward a more accurate grasp of the subject [30].

In the context of momentum and impulse, cognitive conflict can be elicited by presenting anomalous phenomena, such as collision events that challenge students' reasoning and intuition [9]. This can spark curiosity and encourage students to explore further in order to discover scientifically accurate concepts [28], [31]. Implementation of this model is carried out through four systematic phases: (1) activation of preconceptions and misconceptions, (2) presentation of cognitive conflict, (3) discovery of concepts and equations through experiments or virtual laboratories, and (4) reflection [28], [29]. The presentation of these anomalous phenomena is optimally supported by the use of digital technologies such as Google Sites, smartphone-based interactive multimedia [28], and Immersive Virtual Reality (IVR), which can visualize abstract objects resembling their real-world conditions [29].

The application of cognitive conflict in learning holds great potential for correcting misconceptions while enhancing 21st-century skills known as the 4Cs (critical thinking, creativity, collaboration, and communication) [28]. This process of conceptual reconstruction is reinforced by integrating the three pillars of Deep Learning-mindful, meaningful, and joyful learning-to ensure students' deep cognitive and emotional engagement in understanding the essence of the material. The effectiveness of using cognitive conflict-based media has been empirically proven to enhance students' critical thinking abilities, with effectiveness test results showing an N-gain value of 0.78, which falls into the high category [28]. The development of this e-module methodologically follows the systematic Plomp model procedure to produce valid and practical educational products [26]. Overall, this interactive e-module framework is designed to train students' critical thinking skills through features that support intellectual independence [12].

6) Integration of Deep Learning Approaches into E-Modules

In addition to cognitive conflict, deep learning approaches also play a crucial role in improving the quality of learning. These approaches emphasize deep conceptual understanding through three key aspects: mindful, meaningful, and joyful learning [7].

Mindful learning encourages students to learn in a conscious and focused manner through activities that require their full attention to the concepts being studied. In the e-module that has been developed, this is achieved through the use of prompt questions and pre-concept quizzes that systematically activate students' prior knowledge.

Furthermore, the aspect of meaningful learning focuses on the connection between concepts and real-life contexts. In the lessons on momentum and impulse, concepts are linked to everyday phenomena such as vehicle collisions or sports activities, so that students can understand the relevance of physics concepts in their lives [9].

Meanwhile, the aspect of joyful learning is realized through the use of interactive media such as videos, animations, and virtual simulations, which can enhance students' motivation to learn. The integration of multimedia in e-modules has been shown to help students visualize abstract concepts that are difficult to grasp through static text [13], [14]. The combination of these three aspects is expected to create a learning experience that is not only informative but also meaningful and enjoyable for students.

7) The Implications of E-Module Development for Physics Education

The development of e-modules based on cognitive conflict using a deep learning approach has significant implications for improving the quality of physics education. E-modules serve not only as a medium for delivering content but also as a tool for self-directed learning capable of accommodating differences in students' learning styles [14].

Thanks to interactive features, students can learn flexibly at their own pace and according to their individual needs. Furthermore, the integration of cognitive conflict into the e-modules allows students to engage in a more active and reflective learning process, leading to a deeper conceptual understanding rather than mere rote memorization [15], [16].

Furthermore, the use of web-based e-modules also provides students with easy access via various digital devices. This is particularly relevant given that the digital generation is more accustomed to using technology in their daily lives. Thus, the e-modules developed hold great potential to serve as an innovative solution for enhancing students' critical thinking skills in physics education [13], [18].

8) Limitations of the Study

Although this study provides a comprehensive overview of the needs for developing e-modules, there are several limitations that should be noted. This study is still limited to the preliminary research stage and therefore has not directly tested the effectiveness of e-modules in improving students' critical thinking skills.

In addition, the relatively small sample size also poses a challenge to the generalizability of the study's findings. Therefore, further research is needed during the development and evaluation phases to test the validity, practicality, and effectiveness of the e-module on a broader scale [3].

IV. CONCLUSION

Based on the results of the preliminary study, which have been presented in great detail in this article, it can be concluded that high school students' critical thinking skills regarding the topics of Momentum and Impulse currently remain in the very low category, with an average achievement score of only 43.16%. The main challenge identified in the field is the high reliance on conventional teaching materials that are highly procedural and have not been able to optimally facilitate the need for interactive technology in this highly advanced digital era. Therefore, the development of an e-module based on cognitive conflict and a deep learning approach through the Google Sites platform is an innovative solution that urgently needs to be implemented widely at the high school level in Indonesia. The proposed product design meets various strong pedagogical foundations by systematically integrating PbKK syntax and the pillars of deep learning to enhance students' cognitive processes in a comprehensive and meaningful way, thereby supporting their sustained academic progress in the future. The next phase of this research involves the full development of a prototype and testing the product's effectiveness through broader field trials to ensure significantly better physics learning outcomes in the future for Indonesia's youth -who are scientifically literate and intellectually independent—for the nation's advancement in the competitive and cognitively challenging international arena of the rapidly evolving global information age.

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