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Enhancing Individual Critical Thinking and Collaborative Skills: A CinQASE-Based Interactive E-Module for Physics Education

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Abstract: This study aims to develop an e-module based on the CinQASE learning model supported by Flip PDF Professional and evaluate its effectiveness in improving students' Individual Critical Thinking (InCT) and collaborative skills in Momentum and Impulse materials. This study employed an R&D approach based on the 4D development model (Define, Design, Develop, Disseminate), comprising four main stages. In the Define stage, a needs analysis was conducted to identify the essential competencies and materials aligned with the curriculum and students' needs. The Design stage focused on designing the e-module structure, determining learning strategies, and compiling learning components, including worksheets and supporting media. The Develop stage included product development, validation by subject matter and media experts, and revisions based on feedback to ensure content quality and suitability. The Disseminate stage was conducted through limited and extensive trials to assess the practicality, readability, and effectiveness of e-modules in real-world learning contexts. Research instruments included expert validation sheets, student and teacher response questionnaires, collaborative activity observation sheets, and InCT tests to assess individual improvements in critical thinking skills. The results showed that the e-module had very high validity across construct, content, graphics, electronic media, materials, presentation, and language, and was considered practical and easy to use by both students and teachers. N-Gain analysis indicated a significant increase in all InCT indicators, from the moderate category in limited tests (0.40–0.45) to the high category in extensive tests (0.68–0.74). Collaborative activities through CinQASE indicator-based worksheets proved effective in encouraging active participation, critical discussion, and peer evaluation. These findings indicate that CinQASE-based e-modules supported by Flip PDF Professional serve as effective interactive learning media for improving students' critical and collaborative thinking skills, while also providing an engaging, flexible, and accessible learning tool for both teachers and students.

Keywords: CinQASE, e-modul, Flip PDF, critical thinking skills, collaborative abilities, momentum, and impulse.

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INTRODUCTION

Critical thinking skills are an important competency in physics learning, especially when students study conceptual and abstract topics such as momentum and impulse. This ability encompasses the analysis, evaluation, and interpretation of evidence, and the logical drawing of conclusions from available information. The average achievement of students' critical thinking skills in the Impulse and Momentum material is still low, at 31.38%, with details of the analysis indicator at 18.75%, evaluation at 13.87%, and inference/conclusion drawing at 31.48%. Most students fall into the low understanding or misconception category, while only about 12–30% truly understand the concepts in their entirety (Ekayanti et al., 2022; Walsh et al., 2019). Most studies indicate that the critical thinking skills of

high school students in Indonesia remain low to moderate. Surveys across various high schools indicate that more than 50% of students fall into the low or very low category, with only a small portion reaching the moderate or good category. These findings are consistent with reports by Chao & Wright (2025), Fajariyanti et al. (2024), and Khadka et al. (2025), which indicate that overall assessment results for students' critical thinking skills fall within the weak category. This condition emphasizes the need to use e-modules that not only deliver content but also encourage students to engage in higher-level thinking.

This low level of critical thinking is a major challenge in physics learning, particularly in topics such as momentum and impulse, which require an understanding of fundamental principles, including the laws of conservation of momentum and impulse, the concept of force, and interactions between objects. This topic requires not only the ability to memorize formulas but also a deep understanding of the relationships among physical variables and their applications in real-world situations. Learning that does not foster critical thinking yields a superficial grasp of concepts, making it difficult for students to solve problems that require conceptual understanding and scientific reasoning.

On the other hand, collaboration skills are an important 21st-century competency that must be developed alongside critical thinking skills. Modern physics education emphasizes collaboration, scientific communication, idea sharing, and problem-solving. However, several studies show that students' collaborative skills are still low because the learning process tends to focus on individual activities, the use of lecture methods, and a lack of opportunities for students to engage in constructive discussions (Chang-Tik, 2023; Chen et al., 2024; D. Liu & Zhang, 2022). These low collaborative skills result in weak academic interactions, limited idea exchange, and a poor ability of students to build conceptual understanding socially.

In addition to challenges related to student competence, obstacles in learning media further exacerbate the situation. The use of conventional learning media, such as textbooks and printed worksheets, has proven ineffective at fostering the development of critical thinking skills and collaborative abilities (Jiang, 2022; Mugabekazi et al., 2025; Zhao et al., 2025). Passive media make students less engaged because the presentation of material is one-way and does not provide space for exploration or interactivity. As a result, students find it difficult to conduct meaningful analysis, evaluation, and discussion, which are central to exploration-based physics learning. Research by (2024), Han et al. (2025), and Laureate et al. (2023) shows that non-interactive media lead to a superficial understanding of concepts that is difficult to apply to new situations.

Given these issues, there is a need for innovative learning media that stimulate active student engagement, both individually and collaboratively, and encourage students to integrate the processes of questioning, researching, analyzing, and evaluating. In this study, the media developed is a CinQASE-based e-module supported by Flip PDF Professional. This e-module is designed not only to present content but also to facilitate critical thinking activities through a cognitive constructivist approach and Higher Order Thinking Skills (HOTS) principles, which emphasize students' active construction of understanding and the use of analysis, synthesis, and evaluation (Hunaidah M & Erniwati, 2024). The CinQASE model comprises the stages of Questioning, Analyzing, Synthesizing, and Evaluating, which are applied systematically through the Teamwork Collaborative Critical Thinking (TCCT) syntax. In this syntax, each stage of critical thinking is carried out collaboratively in teams. In the Questioning stage, students formulate critical questions about physical phenomena; the Analyzing stage involves identifying key

information and relationships among variables; the Synthesizing stage encourages the integration of findings and concepts; and the Evaluating stage requires teams to assess findings, draw conclusions, and provide feedback. Thus, the CinQASE-based e-module developed with Flip PDF Professional enables the development of critical thinking skills. In the Questioning stage, students formulate critical questions about physical phenomena; the Analyzing stage involves identifying key information and relationships between variables; the Synthesizing stage encourages the integration of findings and concepts; and the Evaluating stage requires teams to assess findings, draw conclusions, and provide feedback. Thus, the CinQASE-based e-module developed with Flip PDF Professional supports the development of both individual and collaborative critical thinking skills, which are highly appropriate and effective for Momentum and Impulse materials, where systematic analysis, synthesis, and evaluation are required in the context of experiments and group problem-solving.

In addition to supporting the development of individual critical thinking skills, the CinQASE model is collaborative, as it encourages students to discuss, exchange views, test ideas, and jointly evaluate the results of their investigations. This means that, although the focus of learning is on improving individual critical thinking, the CinQASE process still involves collaborative elements that are relevant to contemporary learning demands. Thus, this model is well-suited to physics education, as it integrates individual reasoning activities with social interactions that support a more robust conceptual understanding.

The integration of the CinQASE model into flip PDF-assisted e-modules offers a valuable opportunity to provide interactive, flexible, and accessible digital learning media. Flip PDF enables e-modules to be more engaging, incorporating illustrations, animations, hyperlinks, and navigation that facilitate independent learning. Research by Funa et al. (2023) and Weylin et al. (2023) confirms that the use of digital e-modules can increase student engagement, enrich learning experiences, and strengthen conceptual understanding. Thus, the integration of the CinQASE model and the flip PDF platform is a strategic step in designing learning media that suits the characteristics of the digital generation of students.

Based on these conditions, this study was designed to address two main issues: the low levels of students' InCT and collaboration skills in momentum and impulse material, and the limitations of current learning media in supporting the development of these two competencies. The research questions in this study concern the validity, practicality, and effectiveness of the CinQASE-based e-module, supported by Flip PDF, in improving students' InCT and collaboration skills. This study aims to develop an interactive e-module based on the CinQASE model, supported by Flip PDF, on momentum and impulse for 10th-grade high school students, and to evaluate its quality with respect to validity, practicality, and effectiveness in supporting these two main competencies.

This study is expected to provide theoretical and practical benefits. Theoretically, the results of this study contribute to the development of physics learning media based on cognitive-constructivist models. In practice, this e-module can be used as an innovative teaching material that is interactive, easily accessible, and facilitates independent learning. In addition, this e-module is expected to deepen students' understanding of momentum and impulse, enhance individual critical thinking skills, and strengthen collaborative skills relevant to the demands of 21st-century education.

The novelty of this research lies in the development of an e-module based on the CinQASE model, supported by Flip PDF

Professional, which not only emphasizes the development of Individual Critical Thinking (InCT) skills but also systematically integrates collaborative skill development into a single digital learning tool. Although the CinQASE model does have collaborative characteristics, previous studies tend to emphasize only one aspect, either individual critical thinking or teamwork, and thus have not been able to address the real challenges in physics learning, especially on the topics of Momentum and Impulse, which require a deep understanding of concepts as well as the ability to discuss and solve problems collectively.

This study presents a new approach that combines individual and collaborative critical thinking processes through interactive e-modules. This integration allows students not only to formulate questions, analyze information, and draw conclusions independently, but also to evaluate findings with their peers, thereby facilitating the exchange of information and collective construction of understanding. In this way, the uniquely developed digital module overcomes the limitations of prior research, in which students were often trained to think critically individually, without adequate collaborative mechanisms, or, conversely, to collaborate without adequate individualized support. Therefore, this study not only presents a new learning medium but also offers an integrative strategy that supports the simultaneous development of critical and collaborative thinking skills, in line with the demands of the complexity of Momentum and Impulse physics material.

Based on the background and novelty of this study, the research questions asked are how the development of CinQASE-based e-modules supported by Flip PDF Professional can improve students' InCT skills in Momentum and Impulse material, how the e-module can improve students' collaborative skills in learning the same material, and how the integration of individual and collaborative critical thinking processes through interactive e-modules affects students' overall understanding of the concepts of Momentum and Impulse.

METHOD

Participants

Sample selection in this study employed purposive sampling, with N=13 in the limited trial and N=23 in the extensive trial. This sample size was chosen because the study focused on the development and initial validation of the e-module, rather than on producing broad population generalizations. A small sample allows researchers to conduct in-depth observations, evaluate module quality, and collect detailed qualitative and quantitative data, enabling systematic analysis of each participant's responses to refine the product. However, given purposive sampling and a limited sample size, the findings cannot be generalized to the entire population of high school students. The results obtained reflect only the initial effectiveness of the e-module in the selected group of participants and should inform further development or trials with larger samples. The researchers emphasize that the main purpose of this sample size is to validate the product and evaluate its initial effectiveness, not to draw broad conclusions about the population.

Research Design and Procedure

This Research and Development (R&D) study aims to develop an interactive e-module based on CinQASE, supported by Flip PDF Professional, and to assess its effectiveness in improving students' Individual Critical Thinking (InCT) and collaborative skills using Momentum and Impulse materials. The module development procedure employed the 4D model, comprising the Define, Design, Develop, and Disseminate stages. The 4D model was chosen because it provides a systematic, structured framework; facilitates the development of digital learning media that integrate individual and collaborative

critical thinking processes; and enables layered validation to ensure the quality of the module's content and interactivity.

Define

The Define stage aims to formulate learning needs and specifications for developing CinQASE-based interactive e-modules on Momentum and Impulse. Activities in this stage included preliminary analysis, learner analysis, task analysis, and concept analysis. Preliminary analysis was conducted to identify existing problems and learning needs. In contrast, learner analysis aims to understand student characteristics, their level of conceptual understanding, and their critical and collaborative thinking skills. Task analysis was used to identify relevant learning activities, and concept analysis ensures that the material presented is complete and aligned with the expected competencies. The results of the Define stage form the basis for developing the e-module structure, selecting learning strategies, and designing activities that support the systematic development of critical and collaborative thinking skills.

Design

The Design stage involved developing the initial e-module design, selecting appropriate media and formats, and collecting relevant teaching materials to support the Momentum and Impulse material. At this stage, the module structure was designed to be interactive and aligned with the CinQASE model, facilitating students' development of critical thinking and collaborative skills.

Develop

During the development stage, the module design was tested and refined into an interactive e-module. This activity included creating digital content, integrating supporting media, and compiling quizzes and exercises that stimulate critical thinking. The developed e-module was then tested on a limited basis to obtain feedback from teachers and students, enabling improvements before it is widely distributed.

Dessiminate

The Disseminate stage involved distributing and testing the developed e-modules to teachers and students. The modules were distributed via the Flip PDF platform. They are used directly by students to study Momentum and Impulse material, carry out CinQASE activities, and complete the integrated Student Worksheets.

Testing was conducted using purposive sampling: N=13 in the initial trial and N=23 in the follow-up trial, enabling researchers to observe student interactions in detail. During the process, student responses regarding the structure and content of the modules, difficulties encountered, and their level of participation and engagement were recorded. The effectiveness of the modules was evaluated through a combination of pretest-posttest scores and student and teacher response questionnaires. These data provide concrete evidence of the modules' ability to improve conceptual understanding, critical thinking skills, and collaboration, and serve as a basis for refining the modules before wider implementation.

Research Instruments

This study employed four types of instruments to support the development of CinQASE-based e-modules, which assessed the modules' quality and practicality, as well as the improvement in students' critical and collaborative thinking skills. Each instrument was validated by experts and tested for reliability, so that the data obtained was valid and reliable for evaluating the effectiveness of the modules.

First, the expert validation sheet was developed independently by researchers to assess the quality of CinQASE-based e-modules

supported by Flip PDF Professional. This instrument was first validated by three experts (a physics expert, a digital learning expert, and a physics teacher) to ensure the suitability of the indicators, which included the module construct, the suitability of the content with the learning objectives, the clarity and readability of the presentation, the accuracy of language use, graphic and visual display aspects, and the level of media interactivity. The validation results showed a content validity ratio (CVR) of 0.92 and an inter-rater reliability of 0.89, indicating that this instrument is highly valid and reliable for assessing the quality of e-modules.

Second, student and teacher response questionnaires to assess the practicality of the CinQASE-based e-module, supported by Flip PDF Professional, were developed by researchers as an evaluative instrument comprising 7 indicators and 21 statements. The aspects assessed include ease of use, clarity of instructions, readability, content integration, level of interest, media practicality, and support for collaborative learning, and all items are assessed using a 1–4 Likert scale. This instrument was validated by three experts and achieved a content validity index (CVI) of 0.90 and a reliability (Cronbach's alpha) of 0.91, indicating it is a valid and reliable measure of practicality of e-modules.

Third, the critical thinking skills test (pre-test and post-test) was adapted from an instrument developed by Rahman & Rusnayati (2021). The adaptation was made to the operational indicators, question context, and presentation format, without changing the main construct of critical thinking skills. Specifically, the critical thinking indicators based on Ennis' framework were adapted to InCT and the context of momentum and impulse material, including the ability to formulate problems, provide arguments, conduct evaluations, drawing conclusions. The question format was modified from general conceptual questions to contextual essay questions and case studies based on physical phenomena, aligning with the learning activities in the CinQASE e-module. The modified instrument was then validated by three experts (physics subject-matter experts and learning-evaluation experts). The validation results showed a content validity index (CVR) of 0.63 and high internal reliability (Cronbach's alpha = 0.89), indicating that the instrument was valid and reliable for measuring improvements in students' critical thinking skills.

Fourth, the Collaborative Activities of the CinQASE Model (CAC) observation instrument was developed by adapting an instrument from Prayoga & Gading (2023) to assess students' collaborative activities during learning using CinQASE-based e-modules. The adaptation involved adjusting the operational indicators, behavioral descriptors, and observation context to align with the CinQASE learning syntax and the collaborative activities facilitated by the e-module. This instrument measures five main aspects of collaboration, namely compromise, cooperation, responsibility, idea integration, and flexibility, as presented in Table 1. Expert validation results indicated a content validity ratio (CVR) of 0.90 and high internal reliability (Cronbach's alpha = 0.89). Thus, the CAC instrument is declared valid and reliable for measuring students' collaborative skills in CinQASE-based learning.

Table 1. Collaborative activities indicators of the CinQASE model (CAC)

Collaboration Dimension	Collaborative Activities	Description of Student Activities
Compromise	Ask questions or share ideas.	Students actively ask questions, share ideas, or express opinions related to the material in group discussions (Questioning & Analyzing)

Cooperation	Work together to complete tasks.	Students divide roles, help each other, and complete tasks collectively, including synthesizing information (Synthesizing)
Responsibility	Respond to friends' ideas.	Students listen, provide constructive criticism, or support their peers' ideas in accordance with the principles of evaluation.
Integrating ideas	Combine individual thoughts	Students synthesize the ideas of group members into conclusions or final products together (Synthesizing & Evaluating)
Fleksibility	Evaluate group results	Students jointly assess and improve group products or strategies to enhance understanding (Evaluating)

Validasi E-Modul

Module validation was conducted by three expert validators using a 1–4 rating scale, with 1 indicating highly unsuitable and 4 indicating highly suitable. The assessment covered aspects of construction, content suitability, and module presentation. The validation data were analyzed using the Aiken Index to determine the level of agreement between validators, which was then converted into validity categories ranging from low to very high. In addition, the analysis results were also used to assess the consistency of assessments between validators through the assessor agreement index.

Practicality Analysis

The practicality of the e-module was evaluated through student and teacher response questionnaires, which covered the ease of operating the e-module, the clarity of the module display, the suitability of the material to the curriculum, the interactivity of the module, the ease of understanding the instructions, the readiness to use the module independently, and overall satisfaction with the module. The average score for each statement item was calculated by summing all respondent scores, dividing by the number of respondents, and converting the resulting metric to product feasibility categories.

Based on the calculation results, the average score for each statement was converted into a product suitability category using a predetermined assessment range, ranging from very low to very high. These categories reflect the e-module's suitability and ease of use and serve as the basis for improvements before conducting widespread trials.

The practicality category of e-modules was determined based on the percentage of responses from students and teachers. E-modules are categorized as very practical (85–100%), practical (70–84%), fairly practical (55–69%), or less practical (40–54%).

Effectiveness of Critical Thinking Skills and Collaborative Activities

The effectiveness of the module on critical thinking skills was analyzed by comparing pretest and posttest scores using Standard Gain (N-Gain):

Table 2. Standard gain (g) value categories for InCT skill indicators

Standard Gain Value	Category
$(g) \geq 0.7$	High
$0.7 > (g) \geq 0.3$	Medium
$(g) < 0.3$	Low

CAC analysis assesses how CinQASE-based e-modules and flip PDFs facilitate student interaction during Momentum and Impulse learning. The QASE stages enable students to discuss, share ideas, and solve problems collaboratively, making collaboration an

integrated process of coordination and active contribution.

The level of participation in CinQASE Collaborative Activities (CAC) was determined by the percentage of students involved. A percentage of 81–100% is categorized as very high, 61–80% as high, 41–60% as moderate, and 40% or less as low. Collaborative activities within the CinQASE model demonstrate the quality of student collaboration at each stage of learning. These categories were used to assess the effectiv eness of e-modules in supporting collaboration.

■ RESULT AND DISCUSSION

The development process is carried out in stages, beginning with the Define stage, which includes preliminary analysis, learner analysis, task analysis, and concept analysis, to formulate learning needs and clearly specify objectives. The Design stage involves designing the e-module structure, learning strategies, and developing interactive components. The Develop stage includes the creation of digital materials, expert validation, product revision, and the development of worksheets based on critical thinking indicators. The Disseminate stage is conducted through limited and extensive trials to assess the practicality, readability, and effectiveness of the e-module in a real learning context. With this procedure, the development of e-modules is carried out systematically and in a controlled manner, while ensuring the integration of critical and collaborative thinking in Momentum and Impulse materials.

Define Step

The results of the analysis in the Define stage indicate that physics learning still relies on textbooks and does not fully leverage digital media. This condition renders the learning process monotonous, whereas students require more engaging and interactive media. Analysis of student characteristics indicates that 10th-grade students tend to be passive, accustomed to lecture-based instruction, and less involved in discussion and collaboration.

Through concept analysis, materials on momentum and impulse were identified and organized into concept maps to ensure the sequence and interrelationships among concepts. Based on the analysis of basic competency indicators, learning objectives were formulated to guide students' abilities in understanding concepts, analyzing momentum-impulse relationships, and conducting simple experiments. A summary of the Define stage results is presented in Table 3 and serves as the basis for the design of the CinQASE-based e-module.

Table 3. Analysis of learning needs and initial conditions in the define stage

No	Identification of Initial Conditions	Impact on Physics Learning	Identified Needs	Percentage Description
1	Learning is still predominantly teacher-centered and lacks exploratory activities.	Passive students, low participation, and inability to ask questions	A learning model that encourages questioning, analysis, and active discussion	68% of respondents reported that lecture methods still predominate in learning.
2	The use of digital media and e-learning remains limited.	Understanding of abstract concepts is not optimal	Development of interactive e-modules based on CinQASE–Flip PDF	72% of respondents believe that digital media is not being used optimally
3	LKPD remains procedural and does not yet encourage critical thinking.	Higher-order thinking skills (HOTS) are underdeveloped	LKPD/E-modules with explicit Q-A-S-E stages	64% of respondents stated that the LKPD used is still work-oriented.

4	Collaborative activities have not been facilitated	Collaboration, scientific argumentation, and student discussion are still low.	Collaborative and based learning syntax	59% of respondents believe that group work is not yet effective
5	Limited contextual physics teaching materials	Students find it difficult to relate concepts to real-world phenomena.	Physics material based on real-world contexts	67% of respondents reported that the material remained abstract and lacked context.
6	Teachers' understanding of CinQASE is not yet uniform	The implementation of learning innovations is less than optimal	CinQASE model E-module implementation training/guidance	55% of respondents reported not understanding the CinQASE model.

The findings in Table 3 indicate a gap between classroom physics teaching practices and the demands of 21st-century skills-based learning, particularly in critical thinking, collaboration, and the use of learning technologies. The percentage of findings from teachers indicates that innovation, in the form of CinQASE-based interactive e-modules, is needed to overcome these obstacles. Therefore, the results of this define stage analysis provide a strategic foundation for designing more meaningful and effective learning solutions.

Design Step

The results of the Design stage are a preliminary design for a CinQASE-based e-module supported by Flip PDF Professional. This design was compiled based on the findings of the Define stage and produced several main components. First, the structure of the e-module was systematically formulated, comprising an introduction, learning objectives, a presentation of momentum and impulse, CinQASE activities, contextual examples, exercises, and an evaluation.

Second, the format and digital media are delivered as interactive e-modules using Flip PDF, employing visual elements, internal links, and video and image insertions to increase student engagement.

Third, CinQASE activities are designed for each subtopic with an emphasis on questioning, analyzing, synthesizing information, and evaluating problem-solving. These activities are developed to encourage active learning and improve students' critical thinking skills. Fourth, assessment instruments, including case study-based essay questions and collaborative activity observation sheets, are designed to align with learning objectives and the characteristics of the CinQASE model. Fifth, the learning flow is structured in a step-by-step manner, enabling the integration of independent and collaborative learning. The findings from the Design stage are summarized in Table 4 to inform the implementation of the Develop stage.

Table 4. Design components in the CinQASE E-Module design stage

Design Aspects	Design Phase Findings
E-Module Structure	Systematically arranged to include: introduction, learning objectives, description of momentum–impulse material, CinQASE activities, contextual examples, exercises, and evaluation.
Digital Formats & Media	It was decided that the e-module would use Flip PDF Professional, incorporating interactive elements such as internal links, graphics, and video integration.
CinQASE Activities	Each subtopic includes activities on Questioning, Analyzing, Synthesizing, and Evaluating to reinforce problem-based learning and critical thinking.

Assessment Tools	Designed case study-based questions to measure critical thinking skills and CAC observation sheets to assess student collaboration.
Learning Path	The learning flow is structured to integrate independent and collaborative activities, supporting the implementation of CinQASE e-modules in the classroom.

Table 4 presents a summary of the results of the e-module design developed in the Design stage. Findings at this stage indicate that the e-module design has been systematically structured, taking into account the material structure, the characteristics of CinQASE activities, and the integration of Flip PDF-based digital media. In addition, assessment instruments and learning flow were also designed to ensure alignment between learning objectives, content, and presentation strategies. This design serves as the basis for subsequent development during the Develop stage.

Develop Step

The development stage builds on the design stage and aims to implement the initial design of the CinQASE learning model e-module on momentum and impulse. The development of the e-module began with creating a cover in Adobe Photoshop, followed by compiling materials in Microsoft Word using appropriate formatting and typography. The compiled material is converted to PDF and imported into Flip PDF Professional to develop an interactive e-module.

At this stage, the e-module is equipped with various supporting media, such as learning videos, animations, links to Student Worksheets, and "go to page" navigation, to facilitate access to the material. The process of adding interactive media is carried out using the features available in Flip PDF Professional, thereby making the module more engaging and supporting conceptual understanding both visually and practically.

The e-module developed in this study is aligned with the CinQASE learning model, which guides students systematically through the learning stages. The syntax and flow of the CinQASE model implementation in this e-module are presented in Figure 1, facilitating understanding of the steps required in the teaching and learning process.

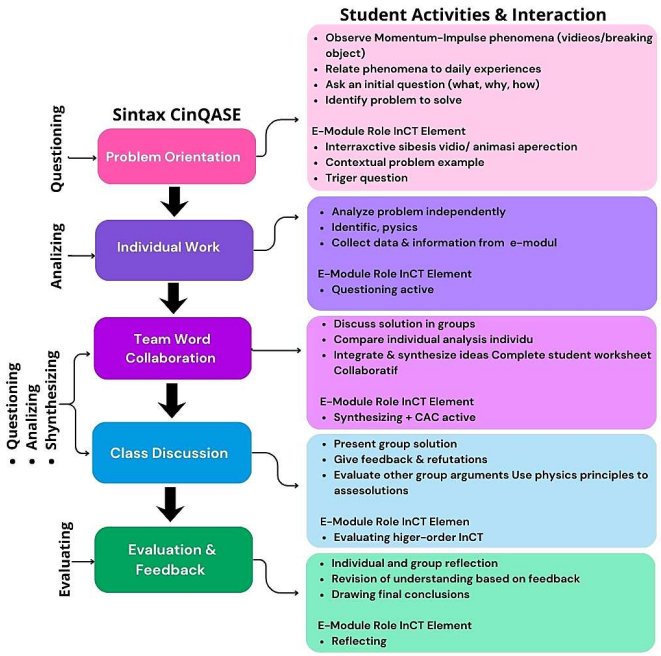

Figure 1. CinQASE learning model syntax (Hunaidah et al., 2022)

Based on the syntax shown in Figure 1, each stage in the CinQASE model is sequentially integrated into the e-module, so that learning activities are not only informative, but also encourage students to think critically and collaborate actively.

CinQASE-Based E-Module Display and Features

The appearance and main features of the e-module, developed based on the CinQASE model, are presented through screenshots that illustrate key aspects of the module, ranging from the main page and material navigation to interactive activities that support the development of students' critical and collaborative thinking skills. Figure 2 shows the e-module cover page, designed to create an attractive first impression while also conveying the module's identity, material title, and development information.

Figure 3 continues the display from the cover page in Figure 2 by showing the design of the first learning activity on the relationship between momentum and impulse, including problem orientation syntax and individual work activities that encourage the development of students' critical thinking skills.

Figure 2. CinQASE-based e-module cover page display

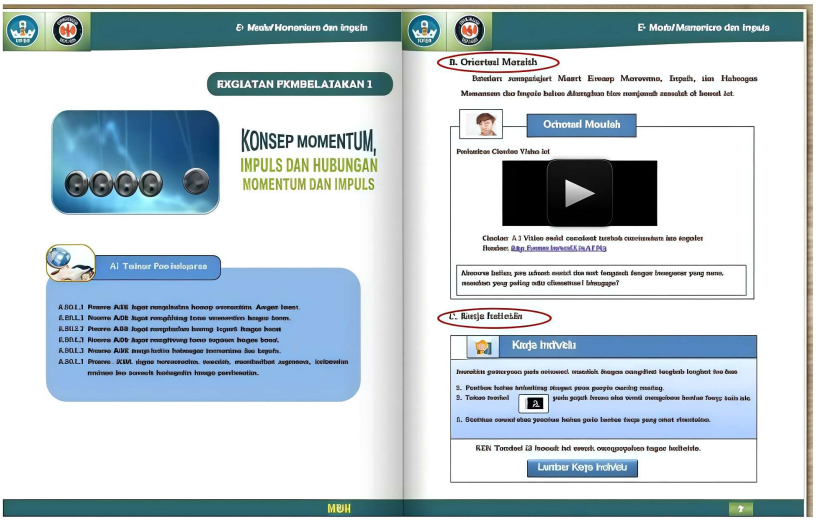

Figure 3. First learning activity design display: the relationship between momentum and impulse with problem orientation syntax and individual work

Continuing from the individual activity design in Figure 3, Figure 4 shows the group worksheet designed for this CAC, which refers to the QASE critical thinking skill indicators, namely Questioning, Analyzing, Synthesizing, and Evaluating, so that each student can actively contribute, discuss critically, develop solutions together, and evaluate their friends' ideas constructively in completing group assignments.

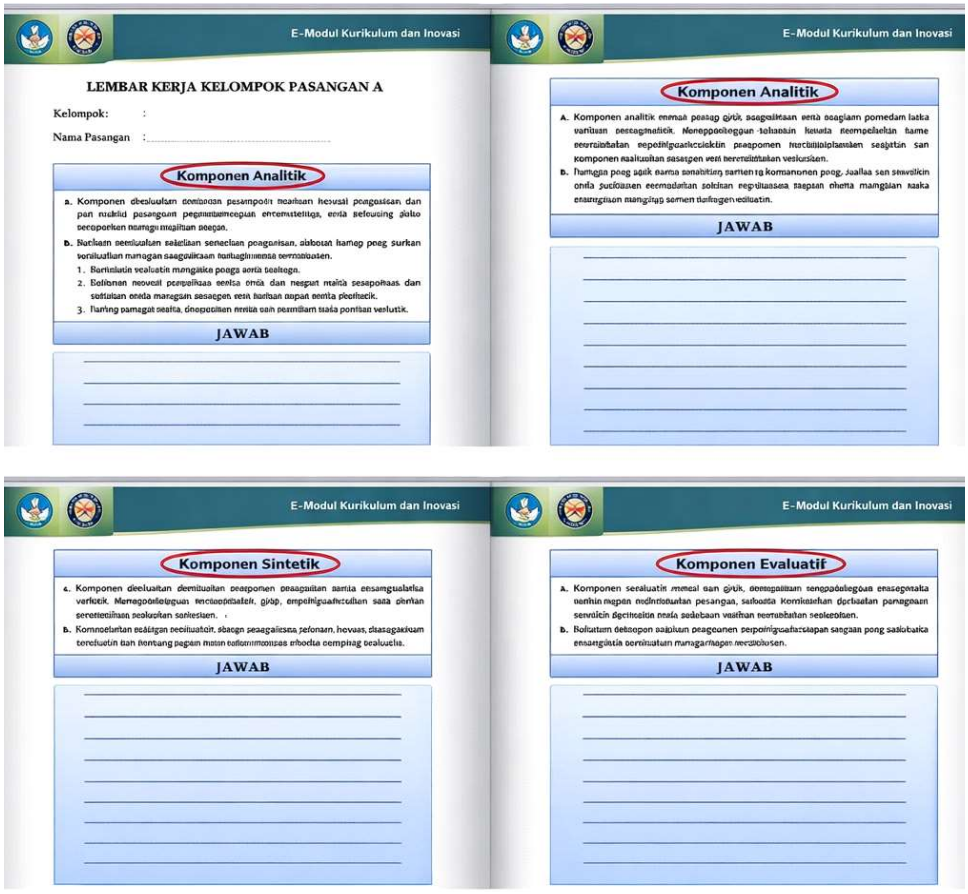

Figure 4. QASE critical thinking skills indicator-based group worksheet

Validity

Before presenting the instrument's validity results, the instrument was reviewed by subject-matter and learning-media experts to ensure its alignment with learning objectives and competency achievement indicators. This instrument includes test questions to evaluate the construct, content, and presentation of the module, as well as a questionnaire to assess students' responses to the CinQASE learning model e-module. Validation was conducted to assess the content's suitability, the language's appropriateness, the format's suitability, and the effectiveness of interactive e-modules in supporting understanding of momentum and impulse.

The validation process serves as the basis for refining the instruments and e-modules prior to implementation in trials. As shown in Table 5, expert assessments confirm that each instrument item can measure InCT skills related to students' collaborative learning abilities. Therefore, the validated instruments can be considered reliable for evaluating the effectiveness of e-modules in enhancing the quality of physics learning in the classroom.

Table 5. Validity results of the CinQASE learning model e-module developed using flip PDF professional

Aspect	Sub-Aspect	$\bar{X}$
Construction	Graphic suitability	0.833
	Electronic media suitability	0.861
	Average construction aspect	0.847
Content	Content suitability	0.788
	Presentation suitability	0.867
	Language suitability	0.833
	Average content aspect	0.829
	Average overall aspect	0.836

The validity results of the CinQASE learning model e-module developed using Flip PDF Professional show that all aspects, both construct and content, including graphic feasibility, electronic media, material, presentation, and language, are in the very high category. These results confirm that the e-module meets high-quality standards, is attractive and easy to understand, and is ready to serve as an effective interactive learning medium to improve students' conceptual understanding and critical thinking skills. Given its high validity, this e-module is expected to have a positive impact on students' InCT in learning momentum and impulse. The high level of product validity can have an impact on increasing students' ability to formulate problems, analyze, synthesize, and draw conclusions, so that their critical thinking skills are also expected to improve (Y. Liu & Pásztor, 2022; Puchongprawet & Chantraukrit, 2022; Tang et al., 2022)

Disseminate Step

Limited Trial

During the trial phase, the Flip PDF-assisted CinQASE e-module was implemented with a small group of students to assess feasibility, practicality, and initial student responses. The results of the observation indicated that learning feasibility was 82–88% (good category). More than 80% of students were actively involved in the Questioning and Analyzing phases.

The critical thinking skills test results showed improvement in the moderate gain category (0.30 d" g < 0.70), whereas the student response questionnaire indicated a positive response rate above 85%. These findings informed minor improvements in the clarity of instructions and the flow of group discussions.

Field Trial

During the field trial stage, the e-module was applied to a larger group of students studying Momentum and Impulse. Learning achievement reached 85–92% (excellent category). Collaborative activities increased, with more than 85% of students actively participating in group discussions and a more balanced distribution of roles.

The test results showed moderate to high gains in individual critical-thinking skills, particularly in the analysis and evaluation of indicators. These findings confirm that the Flip PDF-assisted CinQASE e-module is effective and ready for wider implementation in physics education.

Practicality of Use

During the development stage, the practicality of the CinQASE e-module model was evaluated through two rounds of testing: limited and full. Limited testing was conducted to identify initial obstacles and the initial responses of students and teachers to the e-module, thereby

enabling improvements before it was implemented more widely. The evaluation focused on the ease of operating the module, the clarity of the display, the suitability of the materials, interactivity, the ease of understanding instructions, readiness for independent learning, and overall satisfaction with the module.

The graph of student and teacher responses shows an increase in the percentage of positive assessments across all indicators from the limited test to the extensive test (Figure 5). Student responses increased from the practical category to very practical, whereas teacher responses remained highly consistent across both tests and were further strengthened in the extensive test. These findings confirm that the developed e-module is highly practical and suitable for widespread implementation in education (Aque, 2025; B. Uzoma et al., 2021; Moses et al., 2020).

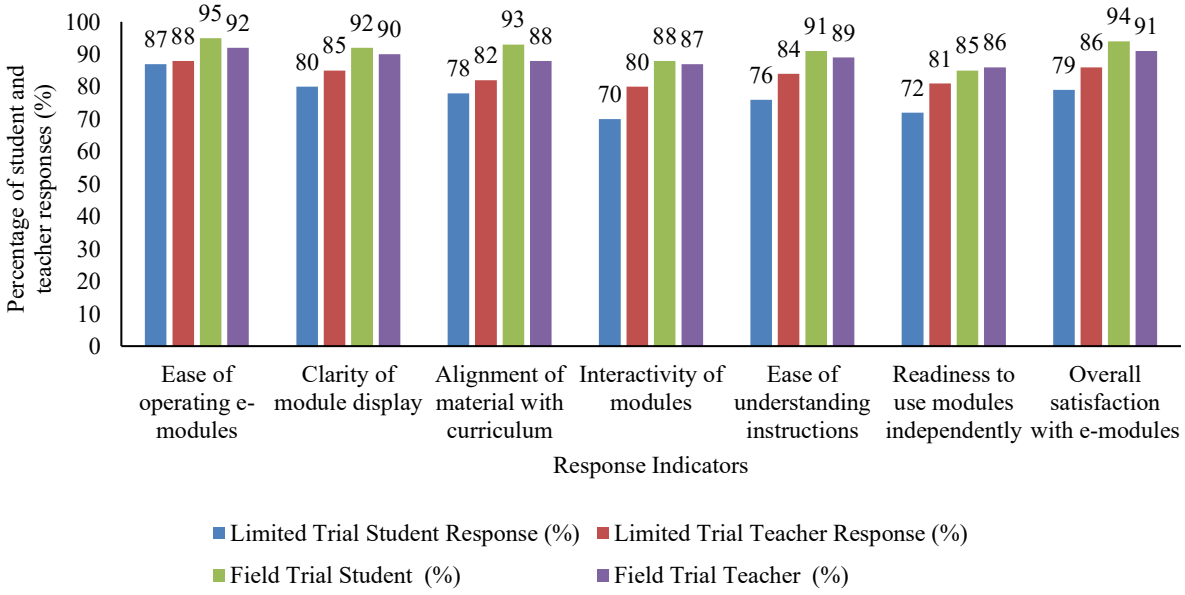

Figure 5. Percentage distribution of student and teacher responses on E-Module practicality indicators in limited and field trials

Improved responses in the field test were attributable to refinements to the e-module based on limited test feedback, particularly in navigation, display clarity, and multimedia integration. Simplified usage flows and more systematic content organization made it easier for students to learn independently and helped teachers manage learning. In addition, a more explicit alignment among the material, CinQASE activities, and the curriculum enhances the perceived relevance and practicality of the e-module across a broader learning context.

These results indicate that the e-module meets the criteria for practicality and is suitable for comprehensive use in physics instruction in public high schools in Southeast Sulawesi, thereby supporting the achievement of basic competencies.

Effectiveness

To fully assess the effectiveness of the CinQASE e-module, the analysis focused on two main aspects: InCT and CAC skills. This approach enables a comprehensive assessment not only of individuals' improved abilities to formulate problems, present arguments, evaluate, and draw conclusions, but also of the extent to which students can work together effectively in

groups. Thus, the following section presents data and analysis on the module's effectiveness based on InCT measurements, before proceeding to an evaluation of collaborative activities.

Individual Critical thinking

The measurement of InCT skills focuses on four main indicators, namely formulating problems, providing arguments, conducting evaluations, and drawing conclusions. These four indicators were selected because they represent higher-order thinking processes that are the primary objectives of CinQASE-based learning. In CT analysis, both limited and extensive tests were conducted to characterize the gradual development of students' critical thinking skills. With this approach, InCT evaluation enables researchers to assess the consistency of improvement, the strength of each indicator, and the contribution of the CinQASE e-module to students' conceptual understanding in physics.

Table 6. Improvement in InCT skills based on n-gain in limited tests (LT) and extensive tests (ET)

InCT Skills Aspects	Indicator	N-Gain LT	N-Gain ET
Formulating problems	Formulate questions that provide direction for obtaining answers	0.45	0.68
Providing arguments	Provide context-appropriate arguments, pointing out similarities and differences with comprehensive reasoning	0.42	0.72
Conducting evaluations	Evaluate based on facts, principles/guidelines, and provide alternative solutions to problems	0.40	0.70
Drawing conclusions	Select possible solutions and determine the actions to be taken	0.43	0.74

The N-Gain calculation results show that all InCT skill indicators experienced a significant increase from the limited test to the broad test. In the limited test phase, all four indicators were in the moderate category with an N-Gain range of 0.40–0.45, indicating that students' initial understanding of critical thinking skills was beginning to form but was not yet optimal. A more noticeable improvement was seen in the extensive test, where all indicators rose to 0.68–0.74, with three indicators falling into the high category. This indicates that the continuous use of CinQASE-based e-modules can strengthen students' abilities to formulate problems, provide logical arguments, evaluate critically, and draw conclusions systematically and evidence-based. The results showed that the use of the module improved Scientific Higher-Order Thinking Skills (S-HOTS), consistent with findings from Trinidad & Despojo about the effectiveness of inquiry-based modules in strengthening critical thinking skills. These findings also confirm the effectiveness of e-modules in supporting active learning processes, as students not only receive information but are also involved in deep thinking processes that consistently trigger improvements in critical thinking skills (Cena et al., 2025; Gold et al., 2025; Meirbekov et al., 2022)

Confirmation of InCT Improvement through Student Essay Answers

To confirm the results of the n-gain analysis, researchers analyzed students' essay answers on the pre-test and post-test for each indicator of

individual critical thinking skills (InCT) on the topic of momentum and impulse. Table 7 presents representative examples of students' essay responses before and after the intervention.

Table 7. Examples of students' essay responses on InCT indicators (momentum and impulse)

InCT Indicator	Pre-test Student Response	Post-test Student Response
Formulating problems	"Why can an object move faster when it is pushed?"	"How does the impulse given to an object affect the change in its momentum when the mass remains constant?"
Providing arguments	"Objects with greater mass move more strongly because they are heavier."	"Momentum depends on mass and velocity ($p = mv$); therefore, an object with greater mass will have greater momentum if its velocity is the same."
Conducting evaluations	"The answer is correct because it seems reasonable."	"This solution is correct because the impulse acting on the object is equal to the change in momentum ($I = \Delta p$)."
Drawing Conclusions	"Thus, impulse and momentum are related."	"A greater impulse results in a larger change in momentum, influenced by force magnitude and interaction time."

As shown in Table 7, students' pre-test responses were generally intuitive and loosely connected to physics concepts. In contrast, post-test responses demonstrated clearer problem formulation, more structured arguments grounded in physics, stronger evaluation skills, and more integrated, evidence-based conclusions. Overall, these qualitative findings confirm that the increase in InCT n-gain values is accompanied by a meaningful improvement in students' reasoning skills, indicating the effectiveness of the CinQASE-based e-module in enhancing students' critical thinking regarding momentum and impulse.

Discussion on the Effectiveness of CinQASE Syntax

Based on the increase in InCT n-gain and analysis of student essay answers, the Analyzing and Evaluating elements in the CinQASE syntax have the most significant impact on the development of critical thinking. The Analyzing stage helps students identify key variables and conceptual relationships. In contrast, the Evaluating stage trains students to assess solutions logically and according to physics principles, as reflected in increased evaluation indicators and improved drawing of conclusions in the extensive test. The Questioning and Synthesizing elements contribute gradually, although initially, students still experience difficulties in formulating conceptual questions and integrating information. The main challenges for students lie in their initial intuitive habits and limitations in critical reflection; however, the structure of activities and the support provided in the CinQASE e-module are consistent.

Collaborative Activities of the CinQASE Model

The effectiveness of the CinQASE e-module in CAC was assessed by monitoring student engagement in each learning session, as measured by predefined collaboration indicators. The observation focused on how students interacted, actively participated, shared roles, contributed, and evaluated their peers' ideas during group activities. With this approach, each indicator can be assessed per session, thereby providing a more detailed view of students'

collaborative skill development and a clearer picture of how the e-module facilitates effective cooperation in the classroom, as illustrated in Figure 6, which shows the CinQASE CAC for each learning session.

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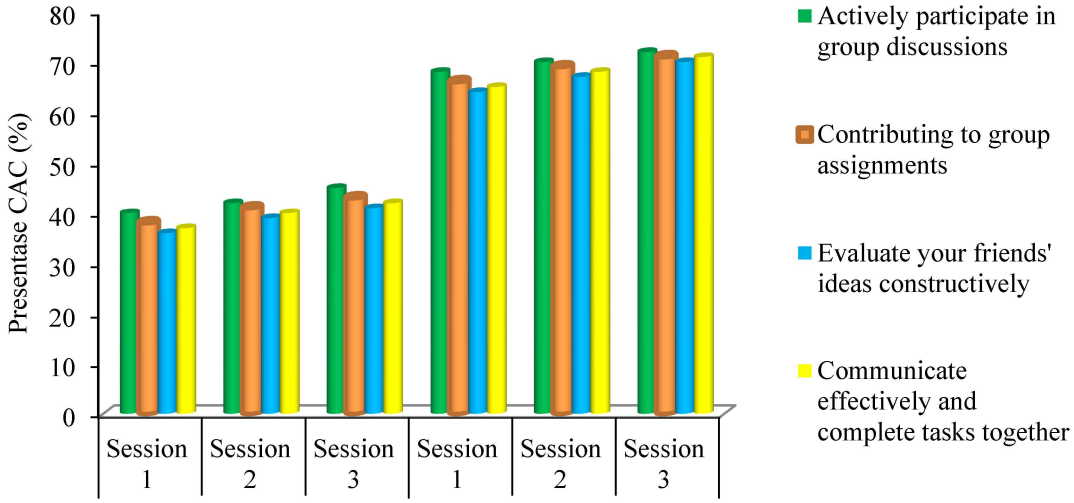

Figure 6. CinQASE collaborative activity chart

interacted, actively participated, shared roles, contributed, and evaluated their peers' ideas during group activities. With this approach, each indicator can be assessed specifically per session, thereby showing the development of students' collaborative skills in more detail and providing a clear picture of how the e-module facilitates effective cooperation in the classroom, as illustrated in Figure 6, which displays a graph of CAC for each learning session (Hu & Shu, 2025; Huang & Ochoa, 2025; Zhu & Ergulec, 2023).

Confirmation of Increased CAC through Learning Observation

The results of the CAC statistical analysis were confirmed through data analysis of student activity observations during learning using the CinQASE-based e-module. In the initial stage, student collaborative activity, as evidenced by the Confirmation of Increased CAC through learning observation, was still suboptimal. After the intervention, students showed improvement in all aspects, marked by an increased willingness to agree on shared ideas, more equitable group member involvement, individual responsibility for group tasks, the ability to integrate ideas, and a more open attitude toward differences of opinion (Fan et al., 2021; Fung, 2022; Lin et al., 2021). Overall, these qualitative findings reinforce the quantitative results, indicating that the use of CinQASE-based e-modules is effective in improving the quality of students' collaborative activities on momentum and impulse.

Research Limitations

This study has several limitations. The study focused on a single physics topic, namely Momentum and Impulse, and therefore, the findings cannot be generalized to other subjects. In addition, the measurement of InCT and CAC was developed based on CinQASE indicators; therefore, it does not encompass all dimensions of 21st-century skills. The duration of the e-module implementation was also relatively short, so the long-term impact of learning could not be identified. Further research should encompass a

broader range of subjects, longer implementation periods, and more comprehensive assessment instruments.

■ CONCLUSION

This study concludes that the CinQASE learning model-based e-module supported by Flip PDF Professional was successfully developed through the 4D model stages and meets the criteria of validity, practicality, and effectiveness for use in physics learning on the topics of Momentum and Impulse. The validity of the e-module was rated very high across all assessment domains, and limited and extensive testing indicated a high level of practicality, with positive responses from students and teachers. In addition, the application of the e-module was shown to significantly improve students' Individual Critical Thinking (InCT) skills, as indicated by an increase in N-Gain scores from moderate to high, and to encourage collaborative skills through CinQASE indicator-based learning activities. The novelty of this research lies in the systematic integration of the CinQASE learning model into interactive digital e-modules supported by Flip PDF Professional, which serves not only as a medium for presenting material but also as a means to facilitate structured individual and collaborative critical thinking. Unlike conventional e-modules, the developed e-module includes explicit learning stages, interactive worksheets, and multimedia support, all of which are aligned with learning objectives and curriculum requirements. In practical terms, the CinQASE e-module can be used by teachers as a flexible and easy-to-implement alternative learning medium for both face-to-face and technology-assisted learning. This e-module also has the potential to support student independent learning and improve the quality of interaction and discussion in group activities. Further research is recommended to test the effectiveness of this e-module with other physics materials or in a broader learning context to strengthen the generalizability of the findings.

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