Design of Teaching Modules Assisted by Computer Vision Integration (CVI) to Train 21st-Century Skills: Critical Thinking and Collaboration in Physics Learning

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Manuscript received April 20, 2025; revised May 15, 2025; accepted August 6, 2025; published January 20, 2026

***Abstract*—The study of physics goes beyond simply transferring knowledge; it also fosters vital skills such as critical thinking, creativity, teamwork, and communication, all of which are crucial for tackling real-world issues. This study aimed to develop a Computer Vision Integration (CVI)-assisted teaching modules, evaluate its validity and practicality, and assess its effectiveness in training students' critical thinking and collaboration skills. This study focuses on development research, utilizing the Analysis, Design, Development, Implementation, Evaluation (ADDIE) model. Data were obtained from 123 high school students and obtained from questionnaire and a test. Techniques data analysis used descriptive statistical analysis. The teaching module developed with computer vision integration is regarded as valid by both experts and practitioners. Students have found it practically effective, and it helps train their critical thinking and collaboration skills. The study's findings recommend the computer vision integration-assisted teaching modules as a suitable learning tool for high schools.**

***Keywords*—critical thinking skills, collaboration skills, teaching modules, computer vision**

I. Introduction

Education plays a vital role in not only providing academic knowledge but also developing the character and skills needed for daily life. The purpose of education is to enhance understanding, intelligence, and moral values, preparing students to face challenges in an increasingly complex world [1]. In the 21st century, education focuses not just on transferring understanding but also on developing essential skills like critical thinking, creativity, collaboration, and communication [2]. These skills are essential for students to adapt to global challenges and contribute positively to society [3].

In modern learning, 21st century skills are vital for students to assess, critique, and use knowledge in practical scenarios [4]. These skills, like critical thinking and collaboration, are essential to an effective learning process, especially in subjects like physics. Collaborative projects, group discussions, and problem-based tasks help students work together, share ideas, and practice communication [5].

Effective physics education requires the integration of 21st century skills, where students not only understand concepts but also engage in experiments that relate to real-life problems [6]. Students need critical thinking skills to formulate hypotheses, collect data, and draw conclusions [7], while group projects encourage collaboration and creativity [8].

However, current physics education often remains limited to theoretical learning, with too much focus on lectures and memorization, which leads to passive learning and difficulty in applying physics concepts to real life [9, 10]. This contradicts Fidan's view that physics learning should be a constructivist process, helping students develop cognitive skills and positive attitudes [11].

Studies by Agnesi's [12] and Ainis's [13] show that critical thinking and collaboration skills among students are still relatively low and need ongoing development. Thus, it is essential to incorporate 21st century skills into teaching materials and use relevant learning models to provide students with optimal learning experiences. Additionally, studies carried out by Tsai *et al*. [14] shows that only 38% of students can demonstrate good critical thinking skills in physics problem-solving tasks, where most students tend to rely on routines and formulas without deeply understanding the concepts. The study also noted that the conventional nature of physics learning, focusing on lectures and individual work, limits students' opportunities to develop critical thinking skills. A similar issue was also found in a study by Bailin *et al.* [15], which revealed that only40% of students in various schools could use critical thinking skills effectively in scientific tasks. In addition, research by Johnson *et al*. [16] although collaboration between students is an important component of science learning, only 45% of students felt they had good collaboration skills in physics group tasks. The findings of this study showed that the teaching method that remains prevalent lead to individualized learning, which reduces effective interaction and collaboration among students. Miller *et al.* [17] also found that only 50% of students engaged in productive group discussions, indicating low collaboration skills in the school physics context. Therefore, it is crucial to embed 21st-century skills into teaching materials and use relevant learning models to provide students with optimal learning experiences [6, 18].

Learning moduless are one type of teaching material available today. Learning moduless designed to develop 21st century skills not only present information systematically but also integrate activities that encourage students to think critically, collaborate, communicate, and innovate [19]. Learning moduless that emphasize 21st century skills help students relate subject matter to real situations, making

doi: 10.18178/ijiet.2026.16.1.2498

learning more relevant and interesting [20]. Furthermore, computer technology-assisted learning moduless play an a crucial role in fostering 21st century skills through the application of innovative learning models that present materials interactively and interestingly, allowing students to learn independently and collaboratively [21, 22]. On the other hand, the combination of learning moduless and computer technology will be more optimal in supporting students' 21st century skills, one of these being the Problem Based Learning (PBL) model. PBL can motivate students to collaborate in groups, fostering critical and creative thinking, as well as problem-solving skills [23]. PBL enables students to work in groups, move, think critically, discuss, and collaborate to solve problems effectively and punctually [24, 25]. The PBL model aims to equip students with skills beyond memorization, beginning with critical thinking, collaboration, communication, and information processing [26].

The outcomes of interviews with physics instructors in schools across the East Lombok district revealed that they had never incorporated computer technology-assisted learning moduless and relevant learning models into the physics learning process to enhance students' 21st century skills, especially critical thinking and collaboration skills. These teachers recognized the significance of incorporating computer technology-assisted learning moduless and suitable learning models into physics education. Additionally, they understood the value of fostering critical thinking skills and fostering student collaboration, which can inspire students to become more engaged in their learning and deepen their comprehension of physics problems. However, they encounter significant challenges in the development of computer technology-assisted learning moduless, leading them to rarely utilize appropriate learning models and instead opt for conventional ones. Overall, they recognize the significance of having access to computer technology-assisted learning moduless and using appropriate learning models to foster critical thinking skills and foster student collaboration.

Researchers have conducted various studies to develop learning moduless that train students' 21st century skills in physics learning. Dewi [27] successfully developed a teaching modules in projectile motion material. Suprapto [28] successfully developed a teaching modules in planetory motion. Pratama [29] successfully developed a teaching modules in rotational dynamics and rigid body equilibrium. Aswirna [30] successfully developed a teaching modules in gas kinetic theory and the laws of thermodynamics material. Haryanto [31] successfully developed a teaching modules in optical tools material. On the other hand, these learning moduless incorporate various computer technology supports, such as virtual reality integration [27, 32] or augmented reality integration [29], although these two moduless provide an interactive learning experience, students are still limited to visualization without involving real-time analysis of experimental data. Our proposed research, which utilizes Computer VisionIntegration (CVI) technology, fills this gap by allowing students to not only view visualizations of projectile motion but also perform live analysis of their experimental data. Through CVI, students can observe the experimental data dynamically and directly, which assists them in analyzing physics variables such as velocity, angle, and distance traveled by the projectile. This provides an opportunity to train students' analytical skills, which cannot be fully achieved by AR/VR-based moduless that only display phenomena without providing tools for direct data analysis. Additionally, there remains a lack of learning models that successfully incorporate students' 21st-century skills, such as critical thinking and collaboration, into the learning process. The purpose of this study is to produce a computer vision integration-assisted teaching modules and test its validity, practicality and effectiveness in training 21st century skills including critical thinking and collaboration skills. We anticipate that the development of computer vision integration-assisted teaching moduless, in conjunction with the PBL learning model, will bridge the gaps in previous research and make a meaningful contribution to the field of education. The uniqueness of this modules lies in its ability to allow students to analyze experimental data in real-time using CVI while collaborating in groups to solve practical physics problems. Thus, students not only gain an understanding ofphysics concepts but are also directly involved in the process of analyzing experimental data, which enriches their critical thinking and collaborationskills. This distinguishes this modules from other technology-based solutions, such as AR/VR, which have not integrated live experimental analysis and student collaboration in practical problem-solving.

This paper consists of several sections, including the Method section, which discusses the development of a computer vision technology-assisted modules for projectile motion experiments and the experimental procedures applied. The Results section presents findings from the modules's application in physics learning, while the Discussion section reviews the modules's impact onstudents' critical thinking and collaboration skills. Finally, the Conclusion section summarizes the research results and suggests further development.

II. Materials and Methods

This study used a Research and Development (R&D) method using the ADDIE model, which comprises five key stages: Analysis, Design, Development, Implementation, and Evaluation. The ADDIE model is commonly used by instructional designers and training developers. Each stage in this model produces results that support the next step, creating an ongoing process of designing and developing learning experiences [33]. The explanation of the study procedures is :

1) Analysis: In the analysis stage, the researcher interviewed physics teachers toidentify the needs and challenges in physics learning in the classroom. The interview focused on the teacher's understanding of the challenges students face in grasping physics concepts and the need for more interactive and technology-based methods. The main findings of the interview were that students have difficulty connecting physics theories with real applications and that critical thinking skills and collaboration in learning need to be improved.modules.
2) Design: modules. In the design stage, researchers designed a Computer Vision Integration (CVI)-assisted

teaching modules incorporating Promotrack to analyze real-time projectile motion. The CVI is integrated with Promotrack, which uses Matlab-based tracking algorithms to visualize and measure projectile motion. Student interaction with the CVI occurs through the Promotrack application interface, where students conduct physics experiments (e.g., projectile launch) and observe the experimental results analyzed in real time. Students then use these experimental results to make analyses, formulate hypotheses, anddiscuss with the group the results they encounter.

3) Development: The development phase is focused on creating the teaching moduless Moduless that include step-by-step instructions for using Promotrack and CVI-based experimental activities and PBL-based learning guides. Expert validation will be used to refine the media. The outcome of this stage is the production of teaching moduless and data collection tools that are validated and ready for classroom implementation.
4) Implementation: The Implementation phase focuses on applying the developed product into practice. The product will be applied in classrooms at the research site schools. During this stage, data will be collected on the improvements in students' critical thinking and collaboration skills, additionally, on the effectiveness of the teaching moduless assisted by Computer Vision Integration. The developed modules is applied in physics teaching, with alearning duration of 3 weeks and two sessions per week. Each session takes about 90 minutes, and students use the Promotrack software integrated modules to conduct experiments and analyze physics experiment data.
5) Evaluation: The evaluation phase involves the tabulation and evaluation of research data. The final outcomes and findings of the study are drawn during this phase, focusing on how students' abilities and the effectiveness of the teaching moduless assisted by Computer Vision Integration have improved.

In summary, Table 1 presents the ADDIE phases in this study, along with the activities and outputs of each phase.

Table 1. The phases of ADDIE

Phase	Activities	Output
Analysis	Interview with teachers to identify learning needs	Students and teachers need to report on physics learning
Design	CVI-assisted teaching modules design with	Promotrack integration Design of teaching modules and experiment guide based on CVI
Development	Print modules creation and Promotrack integration for projectile motion tracking	Printed teaching moduless, Promotrack application ready for use in theclassroom
Implementation	Classroom experiment with the use of the modules for 4 weeks, two sessions perweek	Student experimental data, feedback from teachers and studen
Evaluation	Data collection through pretest, posttest, and questionnaire	Evaluation report on modules effectiveness in improving 21st-century skills

The effectiveness was assessed through a control group with pretest and posttest design. Using cluster random sampling, three schools were selected. The class structure for this study is shown in Table 2, with identical pre-test and post-test questions applied across all classes.

Table 2. Pretest-posttest control group design

School	Pretest	Intervention	Posttest
S01	O_1	X_1	O_2
S02	O_1	X_2	O_2
S03	O_1	X_3	O_2

Note: O_1 is pretest critical thinking and collaboration skills;
O_2 is posttest critical thinking and collaboration skills;
X_1 is learning through textbooks in school and using the lecture method;
X_2 is learning through teaching modules assisted by Computer Vision Integration (CVI) through promotrack software;
X_3 is learning through teaching modules in pdf format

Table 2 illustrates the design of the pretest-posttest control group, which served to compare the changes that occurred before and after the intervention in each school. O_1 represents the pretest measurement taken before the intervention began to assess students' initial ability. X_1, X_2, and X_3 represent the interventions given to each of the different schools (S01, S02, and S03). Represents the posttest measurement conducted after the intervention was completed to assess the changes that occurred in students' abilities after using the modules.

The study was carried out at a senior high school in East Lombok, Indonesia. Three schools were selected to be involved in the study. The study consisted of 123 students from three senior high schools (S01, S02, and S03). The participants were chosen through cluster random sampling, a method where groups of students are randomly selected from classes, without focusing on individual population levels. The researcher chose three different schools for this study because they are all located in the same sub-district cluster area, which means they share similar characteristics and contexts. Additionally, the curriculum used in each school is identical, ensuring uniformity in the learning approach. Furthermore, each school has a limited number of students, with only one study group per grade level. Students involved in this study were selected based on several inclusion criteria, including: 1). Students in grade XI IPA from each school; and 2). Students with physics scores that meet the minimum completeness determined by the curriculum, namely those with a physics score of more than70 in the final semester exam. In addition, the exclusion criteria included students with physics scores below 70 who were considered not to have met the minimum completeness in physics subjects.

The study utilized a variety of data collection tools, including both test instruments and non-test instruments. The test instruments comprised multiple-choice items aimed at evaluating critical thinking skills. Meanwhile, collaboration skills were measured through a non-test instrument using an an observation questionnaire. Additionally, non-test instruments such as interview forms were employed. All instruments used for data collection were initially validated by expert and practitioner validators and were confirmed to be valid prior to their use. Each question in the test instrument corresponds to a specific indicator of critical thinking. The test instruments have undergone limited trials and are considered valid and reliable, due to their validity, reliability, and question difficulty indices, as assessed using the SPSS application.

The teaching modules assisted by Computer Vision Integration (CVI) was validated by validators, consisting of 7 people, including 4 experts (A01, A02, A03, and A04) and 3 practitioners (P01, P02, P03, and P04). Experts and practitioners review the validity criteria of the questionnaire on a 5-point scale using Aiken's V formula (Eq. 1) along with the requirements outlined in Table 3. The scale allows for a clear and objective assessment of each item in the questionnaire. This helps in ensuring the accuracy and reliability of the questionnaire's content.

$$V = \frac{\sum S}{n(C-1)} \quad (1)$$

Table 3. Aiken's V requirements

V Index	Requirements
<0.4	Not Valid
0.41–0.80	Valid
0.81–1.0	Very valid

The practicality tests was assessed through user response questionnaire data. The average percentage results obtained show the practicality of the product developed, providing valuable insights into its usability and effectiveness. The criteria listed in Table 4 assess the practicality of the teaching modules supported by Computer Vision Integration (CVI).

Table 4. Practicality criteria

Score Interval (%)	Criteria
$P \leq 54$	Not Very Practical
$54 < P \leq 59$	Not Practial
$59 < P \leq 75$	Pretty Practical
$75 < P \leq 85$	Practical
$85 < P \leq 100$	Very Practical

Subsequently, the study results were analyzed using SPSS 26. In this phase, a two-group test was performed to assess the variations in the improvement of critical thinking and collaboration among the participants. Data analysis methods employed at this stage included normality tests, homogeneity tests, n-gain analysis, and effect size analysis to assess the effectiveness of media usage. The following data analysis techniques were used.

Normality tests were carried out to assess whether the samples followed a normal distribution. The normality testing was performed using SPSS 26, utilizing the Shapiro-Wilk test. The test was considered significant if the Sig value was > 0.05, this means the sample comes from a normally distributed population. If the normality test shows that the data is not normally distributed ($p < 0.05$), we will use the Kruskal-Wallis test to compare the differences between the groups. Kruskal-Wallis was used because non-normalized data requires a non-parametric test that does not assume a particular distribution. Therefore, the Kruskal-Wallis test was utilized to see how the control group and the experimental group are different.

The homogenity test was conducted to check if the two groups are homogeneous. A significance level of $\alpha = 0.05$ was used as the criterion for homogeneity. If the obtained significance was greater than α, it indicated that the variances of each sample were equal, meaning the groups were homogeneous, and vice versa.

Effect size analysis was employed to measure the impact of learning through Computer Vision Integration teaching moduless on enhancing students' critical thinking and collaboration skills. The effect size was determined by calculating Cohen's f value from the eta square (η^2) value transformation using the specified equation:

$$f = \sqrt{\frac{\eta^2}{1-\eta^2}} \quad (2)$$

The effect size obtained was interpreted using the classification system created by Cohen's [34], presented in Table 5.

Table 5. Classification of the effect size

Effect Size	Interpretation (Effect)
0–0.20	Weak
0.21–0.50	Modest
0.51–1.00	Moderate
>1.00	Strong

Students' improvements are evident in their pre-test and post-test scores, as well as the N-gain value, which can see in Table 6.

Table 6. N-Gain score criteria

Score Interval	Criteria
$(g) < 0.3$	Low
$0.7 > (g) \geq 0.3$	Moderate
$(g) \geq 0.7$	High

III. Result and Discussion

The study findings from the development of computer vision integration-assisted teaching moduless have resulted in moduless specifically designed for senior high schools. This study also included a validation assessment conducted by four expert validators and three practitioner validators, along with an assessment of 123 respondents, including senior high school students. The moduless were developed using the ADDIE model, an iterative process that takes into account multiple factors to achieve optimal results. The ADDIE model consists of five stages, each stage plays a critical role in creating and refining the modules. Below is an explanation of each stage.

A. Analysis Stage

The first phase of this study focuses on analysis, which includes three main activities: material analysis, literature review, and student/environmental analysis. The material analysis identifies the necessary competencies students need to acquire, including core and basic competencies, materials, assessment tools, and indicators. In the literature review, existing research is examined to support the development of the teaching product. The student analysis aims to identify the challenges students face during learning, using observations during lessons to gather insights on teaching methods, tools, and student behaviors. Interviews with teachers further help in understanding the requirements of teachers and students.

Initial observations and interviews with students and teachers revealed that the main learning media consisted of blackboards, along with occasional use of worksheets and textbooks. There was no use of technology in learning. While teachers acknowledged the effectiveness of computer-based, its implementation had not yet occurred due to the absence of computer-based media for physics, particularly those incorporating Computer Vision, for both teachers and students. Observations also revealed that students appeared engaged during lessons, showing enthusiasm for achieving high scores in quizzes. However, their performance in projectile motion material was still suboptimal. Students expressed interest in learning through computer-based media that offers strong kinetic and visual elements. As a result, educational media incorporating kinesthetic aspects through experiments and visual elements using Computer Vision will be developed.

B. Design Stage

The design of the teaching modules assisted by Computer Vision Integration (CVI) is created based on the analysis presented in section B. In this stage, teaching moduless are developed with the integration of computer vision, and assessment instruments for critical thinking and collaboration skills. The design for the product specification is created as follows: 1). The product developed is a teaching modules that can be used as a learning resource assisted by computer vision technology; 2). The product developed is named a physics modules for projectile motion material assisted by computer vision. The material presented consists of learning activity 1, student worksheets, summaries, practice questions, bibliography, glossary, and author biography; 3). The product display is a printed modules; and 4). The developed product integrates computer technology, specifically computer vision from Promotrack software.

There are several stages in the manufacturing process of the product, including; 1) Identify content for the modules; 2) Design covers and backgrounds in CorelDRAW; 3) Insert material and images in Microsoft Word, adjusting font and layout; 4) Add link or QR code for Promotrack integration; 5) Convert to PDF; 6) Print/publish.

This research developed a physics modules on projectile motion to train students' critical thinking and collaboration skills. The modules was designed by integrating computer vision technology with the developed modules. Therefore, it required assessment aspects and indicators to measure critical thinking and collaboration skills, which were developed in this modules. The critical thinking skills consists of 10 aspects and indicators [35–38], while collaboration skills consists of 4 aspects and indicators [36, 39–41] as shown in the Table 7.

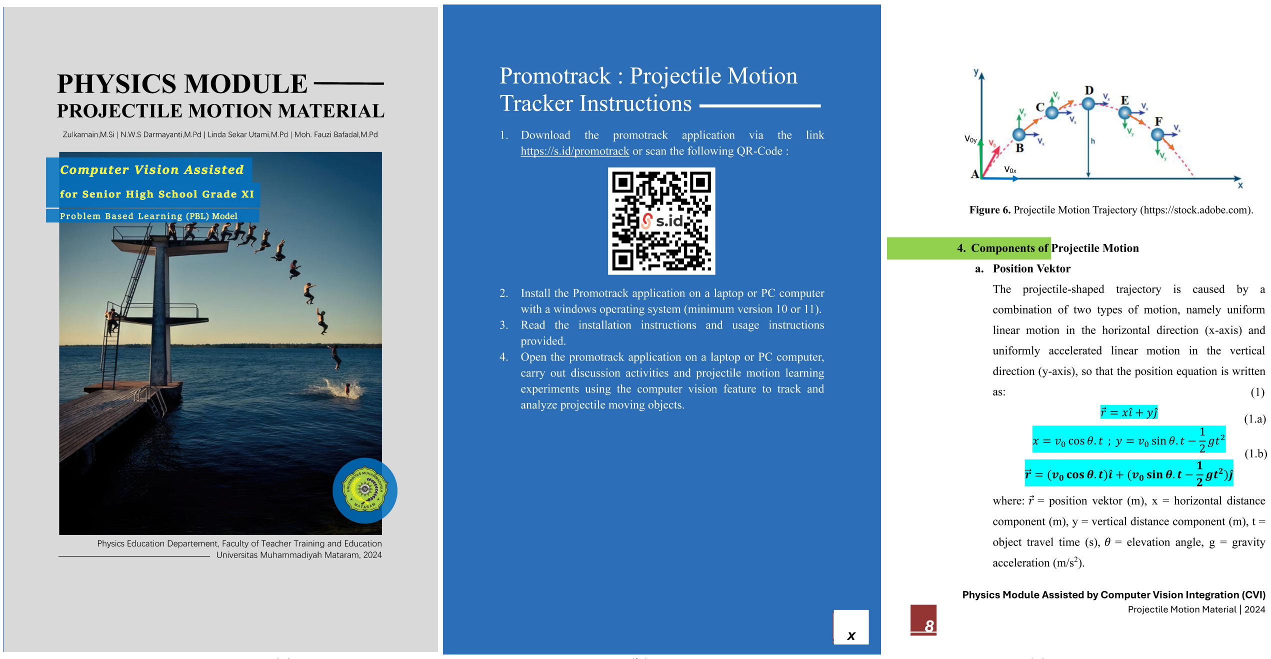
Table 7. Assessment aspects and indicators of critical thinking and collaboration skills

Skills measured	Assessment Aspect	Indicator
Critical thinking skills	Assess students' understanding of projectile motion by assessing their ability to explain its description comprehensively.	Examine the description of projectile motion
	Evaluate students' problem-solving skills related to projectile motion by observing real-world physical phenomena.	Solve problems of projectile motion characteristics in an observation of physical phenomena
	Assess students' skills in organizing information about the physical quantities involved in projectile motion (e.g., speed, time, and distance).	Organizing physical quantities in projectile motion
	Assess students' ability to compare the results of calculations or experimentson the maximum height and farthest distance based on different elevation angles	Comparing the maximum height and farthest distance with different elevation angles
	Measure students' ability to analyze the physical phenomena of projectile motion described, both in theoretical and experimental contexts	Examine the utilization of the physical phenomenon of projectile motion in the picture
	Assess students' ability to solve problems related to elevation angle in projectile motion phenomena	Solve problems characterizing projectile motion
	Assess students' ability to analyze data or the results of experimental images related to projectile motion	Solve elevation angle problems in physical phenomena of projectile motion
	Assess students' ability to analyze data or the results of experimental images related to projectile motion	Analyze the data from the picture of the experiment on projectile motion
	Measure students' ability to evaluate how velocity, distance covered, and elevation angle are interconnected, and link these concepts to experimental data regarding projectile motion.	Investigate how velocity and angle of elevation relate to the maximum distance based on the data from the projectile motion experiment.
	Assess students' ability to conclude the analysis results related to the relationship between velocity, farthest distance, and elevation angle based on projectile motion experiment data	Conclude the results of analyzing the relationship between velocity and the farthest distance and elevation angle with the farthest distance based on datafrom projectile motion experiment images
Collaboration skills	Actively participate and contribute	Demonstrate a professional attitude with others in promptly designing projectile motion experiments as expected
	Actively participate and contribute	Show respect for different opinions in the discussion of designing projectilemotion experiments and be active in presentation activities
	Take responsibility together to complete the task (projectile motion experiment)	They should know how to plan, organize, and fulfill the projectile motion experiment tasks the teacher gave and how to hold their functions
	Respect the ideas of others	Responding with an open mind to different ideas when conducting presentation of the results of analyzing the data obtained from the projectile motion experiment and appreciating new ideas from others

C. Development Stage

The next stage is development, which involves implementing the work completed in the previous stage. In this research, we created a physics teaching modules on projectile motion material, assisted by Computer Vision Integration (CVI). This development builds upon previous research, in which we created a 2-D motion tracker using computer vision. The findings show that the previous application project was validated as very good, deemed very practical in practicality testing, and enhanced students' laboratory skills according to effectiveness evaluations [42].

Further research is necessary to continue developing various learning devices that create more engaging and interactive learning experiences, ultimately improving learning effectiveness. This year's research resulted in the creation of a teaching modules that integrates the previously developed application project with computer vision. Fig. 1 shows the appearance of the developed teaching modules.



(a) (b) (c)

Fig. 1. Example of modules section interfaces: (a) Cover of modules; (b) User guide of promotrack; (c) Example of material page.

The product developed is a physics modules in printed form. This modules incorporates Computer Vision technology from the Promotrack application to analyze projectile motion in real-time. The projectile motion material was chosen based on the curriculum applicable in the research location school. Fig. 1 presents some parts of the overall modules content. More details about the contents of the entire modules can be accessed through the page https://s.id/teachingmodules. This modules contains instructions for using themodules, core competencies, fundamental competencies and indicators, learning objectives, concept maps, instructions for using promotrack, projectile motion material, a brief review of computer vision, student worksheets containing projectile motion experiments assisted by promotrack applications, practice questions, summaries, bibliographies, glossaries, and author bios. This modules includes a marker in the form of a barcode scan to be directed to a link that can be used to download the Promotrack application, installation instructions on a computer/laptop, and instructions for use. Computer vision technology from the Promotrack application will be integrated into learning when students conduct experiments on projectile motion contained in the student worksheet in the modules. Real-time visualization of projectile motion through the Promotrack application to detect the position of objects, analyze their motion trajectories, and identify influencing physical variables such as launch angle, speed, travel time, distance, and altitude can assist students in grasping the concept of projectile motion.

Promotrack is software that uses Computer Vision to analyze the motion of projectile objects in physics experiments. The system involves a camera connected to Computer Vision technology to track the projectile's movement, detect its position in each frame, and calculate essential variables such asspeed, launch angle, and distance traveled. With Promotrack, students can see how changes in variables such as speed or launch angle affect the projectile's trajectory in real-time, providing a data-driven learning experience rather than just theory or static images. The device also displays graphs of the trajectory, velocity, time, and distance traveled of the projectile, making it easier for students to analyze motion more intuitively.

Unlike other teaching tools that only show static animations or graphics, Promotrack allows direct interaction with the experiment and provides instant feedback. With Computer Vision, Promotrack delivers accurate and relevant experimental data, giving more profound insight into projectile motion.

The final product of the developed teaching modules was tested for content validity, covering three key aspects: material, graphics, and language. The testing involved 7 validators, including 4 experts (A01, A02, A03, and A04) and 3 practitioners (P01, P02, and P03), who conducted a thorough review of the modules. The content validation test was evaluated through Aiken's V formula [43], with the results presented in Table 8, offering a detailed assessment of the modules's content validity.

According to Aiken [44], the lowest value that has been approved by seven experts must exceed 0.75, based on Aiken's V table. Fibonacci's [45] and Ahmad's [43] studies also agree with this recommendation, which sets a validity value higher than the lowest value of 0.40 as acceptable validity. However, based on Aiken's approach, the closer an item is to 1, the more valuable it is, as it more accurately reflects the indicator. According to an expert assessment, 30 items from the instrument as a whole fulfil the minimum requirements ($V > 0.75$). The expert panel concurred with the items included in the instrument. One item received the highest V index, namely the modules component related to illustrations and image captions ($V = 0.9826$).

According to Berger [46], the presentation of illustrations and image captions in a teaching modules plays a crucial role by assisting and guiding the students' thinking process in the direction expected by the educator. This aligns with the views of Turkay [47] and Daly [48], who state that images are the most straightforward, practical, and easily created visual messages, making them highly valued by students. Specifically, image illustrations help students navigate the teaching modules, particularly in understanding and retaining the content of the accompanying text material. In summary, 30 items are validated based on expert assessments (see Table 8). This indicates that the teaching modules is considered valid and satisfies the content validity requirements. This study's findings rely on the perspectives of the opinions of Sofyan [49] and Bani [50], who stated that all learning devices validated by the validator are valid. So, the teaching modules can be said to be valid if it uses Aiken's V as part of the content validity test and is validated by a validator, which is what has been done. The teaching modules's validity assessment includes improvement suggestions from three validators, as shown in Table 9.

Table 8. Content validation results of media

Aspect	Item	*V* index	Criteria
Material	Item 1	0.8571	Valid
	Item 2	0.8929	Valid
	Item 3	0.8571	Valid
	Item 4	0.8214	Valid
	Item 5	0.7500	Valid
	Item 6	0.7857	Valid
	Item 7	0.8214	Valid
	Item 8	0.8214	Valid
	Item 9	0.8214	Valid
	Item 10	0.7500	Valid
	Item 11	0.8929	Valid
	Item 12	0.8214	Valid
	Item 13	0.8571	Valid
	Item 14	0.7500	Valid
	Item 15	0.8214	Valid
Grapic Attraction	Item 16	0.8214	Valid
	Item 17	0.7500	Valid
	Item 18	0.8214	Valid
	Item 19	0.8929	Valid
	Item 20	0.8571	Valid
	Item 21	0.8214	Valid
	Item 22	0.9286	Valid
	Item 23	0.7857	Valid
	Item 24	0.8571	Valid
	Item 25	0.8214	Valid
Language	Item 26	0.8214	Valid
	Item 27	0.8571	Valid
	Item 28	0.8571	Valid
	Item 29	0.7857	Valid
	Item 30	0.8929	Valid

Tabel 9. Experts and Practitioners Suggestion

No	Validator	Suggestion
1	A01	The modules arranges the student worksheets in accordance with the syntax of the used learning model.
2	A04	The practice question format can be further developed with a two-tier level or higher.

Based on Table 9, Expert Validator A01 offered recommendations for enhancing the modules, specifically focusing on the arrangement of student worksheets by the learning model's syntax. The modules employs the PBL model as its learning model. According to Hasanah [51], student worksheets in a teaching module are essential for a structured and effective learning process, especially when aligned with the applied learning model. Student worksheets can enhance understanding, develop critical thinking, and boost engagement in learning activities. As a result, it is critical to design student worksheets that are not only attractive but also consistent with the learning model's syntax in order to achieve optimal learning outcomes. Furthermore, Validator A04 offered suggestions to enhance the practice question format, enabling the development of questions beyond the one-tier level. Irnin [52] and Çelikkanlı [53] concur that the integration of multi-tier questions, encourages students to not only comprehend fundamental concepts but also to apply, analyze, and evaluate information thoroughly. Higher-level questions challenge students to question assumptions, formulate arguments, and find creative solutions to problems, thus honing their critical thinking skills. Variations in question types also encourage students to think systematically and reflectively, increasing their involvement in the learning process.

The critical thinking and collaboration instruments was tested for content validity, covering three key aspects: content, construct, and language. Both instruments have been declared valid and have undergone empirical testing to ensure their validity and reliability. The instrument validation results are presented in Table 10.

Table 10. Content validation results of critical thinking and collaboration instruments

No	Item	V index	Criteria
1	Item 1	0.7500	Valid
2	Item 2	0.7500	Valid
3	Item 3	0.7500	Valid
4	Item 4	0.9375	Valid
5	Item 5	0.8750	Valid
6	Item 6	0.8125	Valid
7	Item 7	0.9375	Valid
8	Item 8	0.8125	Valid
9	Item 9	0.7500	Valid
10	Item 10	0.7500	Valid
11	Item 11	0.7500	Valid
12	Item 12	0.7500	Valid
13	Item 13	0.8125	Valid
14	Item 14	0.8125	Valid
15	Item 15	0.7500	Valid
16	Item 16	0.7500	Valid
17	Item 17	0.7500	Valid

Table 10 shows the validation results for the 17 items used in this study. Items are evaluated for content validity using the *V* index. Based on the validation results, all items have a V value > 0.75, which indicates that all items can be considered valid. The V index value for each item varies between 0.7500 and 0.9375, which means a good level of validity by the minimum criteria set.

After being declared valid, critical thinking skills and collaboration instruments underwent Cronbach's alpha analysis to determine their reliability. Reliability analysis was conducted using SPSS, as shown in Table 11.

Table 11. Instrument reliability result

Cronbach's Alpha	N of Items
0.898	4

Based on the Cronbach's Alpha results obtained from Table 11, the Cronbach's Alpha value for the instrument is 0.898, indicating excellent reliability. Generally, a value between 0.6 and 0.7 is acceptable, while 0.8 or higher reflects very high reliability [54], it reliably assesses critical thinking and collaboration skills.

After analyzing the products and test instruments declared valid and reliable, the research can continue to the next stage, namely conducting large-scale trials or classroom implementation.

D. Implementation Stage

This implementation stage was carried out in three classes listed in Table 1. Class X_1 used the school textbook, class X_2 used the modules assisted by Computer Vision Integration (CVI) technology through the Promotrack application, and class X_3 used the modules in PDF format. In addition, a questionnaire was administered to measure students' responses to media usein this trial. The results showed a positive response, with an outstanding assessment category (Table 8). The learning activities can be seen in Figs. 2–4.

Fig. 2. Learning in class X_1.

The learning process was conducted in two sessions. The learning took place in the research class using the product that had been developed, namely class X, and applying the PBL model. The phases in this learning model include: 1) Problem Introduction, where students are introduced to are levant and interesting problem to study. 2) Problem Identifi cation: at this stage, students work in groups (collaboration) to identify the main problems that need to be solved, formulate the problem in more detail, explore important issues, and determine parts of the problem that are unclear or require further research. 3) Information Gathering: students research to gather information needed to solve the problem. 4) Analysis and Discussion: students analyze and discuss the collected data to better understand the problem. 5) Problem Solving: students compile possible solutions to the problem based on the analysis and discussion, then select the most appropriate solution and develop arguments to support their choice. At this stage, creativity and critical thinking skills are needed. 6) Solution Presentation and Evaluation: students present the solutions they have found in front of the class or the form of a report. In addition, this stage allows the teacher or other students to provide feedback and evaluate. 7) Reflection and Assessment: after problem-solving and evaluation, students reflect on what they have learned during the problem-based learning process. The methods applied in this learning design include experimentation, discussion, presentation, and question and answer. This learning design consists of two meetings. The material of Introduction to 2D Motion is discussed in the first meeting, and in the second meeting, the material of Projectile Motion is discussed. Experiments are carried out during group data collection; discussions are held when students work on experiments to conclude; presentations are made when students present the results of their discussions; and continued with questions and answers are when students respond to the results of group discussions that have been presented. In learning using the teaching modules based on Computer Vision Integration witha problem-based learning model, it was found that students showed high enthusiasm for using the modules and Promotrack software. Computer vision technology offers an innovative experience for students, which makes them more active and enthusiastic in learning this technology through Promotrack software. In addition, the high enthusiasm of students also makes them more interested, makes it easier to understand, and helps them remember the material about projectile motion.

Fig. 3. Learning in class X_2.

Fig. 4. Learning in class X_3.

E. Evaluation Stage

The implementation and evaluation phases occur concurrently. The product that has been developed is then tested on users, in this case, students. During the evaluation phase, the product undergoes both formative and summative assessments. Formative evaluations are conducted at each stage to improve the teaching modules, while summative evaluations measure overall user feedback, helping to assess its effectiveness and user satisfaction.

The practicality of the teaching modules on users, in this case, students from three senior high schools (S01, S02, and S03), totaling 123 students. The practicality of the teaching modules was reviewed from several aspects, including attractiveness, material, and language. The results of the users' practicality assessment are presented in Table 12, which highlights the modules's overall effectiveness and reception by the students.

According to the results presented in Table 12, the practicality test results for the modules among students reached an average score of 4.50 with a percentage score of 90.07% for the graphic attractiveness aspect, falling under the 'very practical' criteria. The material aspect achieved an average practicality value of 4.45 with a percentage score of

89.07%, also meeting the 'very practical' criteria. Lastly, the language aspect received an average practicality value of 4.48 with a percentage of 89.67%, similarly classified as 'very practical.

Table 12. Practicallity results

Aspect	S01	S02	S03	Average	Percentage (%)	Citeria
Graphic Attraction	4.43	4.49	4.59	4.50	90.07	Very Practical
Material	4.46	4.44	4.46	4.45	89.07	Very Practical
Language	4.47	4.44	4.54	4.48	89.67	Very Practical
Average				4.48	89.6	Very Practical

Asmianto [55] asserts that the attractiveness aspect of the teaching modules garnered the highest practicality score, indicating a connection between it and student learning motivation. A high level of student motivation often leads to optimal learning outcomes, and motivation is crucial in enabling students to learn independently [56]. Therefore, the modules's attractiveness in this study is expected to support students in studying the material independently, enhancing their overall learning experience. Zhao [57] supports the importance of material organization in a teaching modules, emphasizing its role in facilitating learning activities. The organization of materials and technology within the modules is crucial for students' ease of use, which directly influences their learning outcomes [58]. Additionally, the language aspect of the modules plays a key role, as Hasanah [59] confirms that language acts as a communication bridge between the delivery of information and participants' understanding. The use of clear, precise, and simple to comprehend language can enhance participant involvement, minimize misunderstandings, and support a more effective learning process.

Overall, the practicality test for the teaching module received an average score of 4.48, which translates to 89.6%, classifying it as 'very practical' and showing that students highly value it. This indicates that students find the developed teaching modules highly practical, with the results suggesting that the modules is suitable for physics education and holds significant practical value across all dimensions. The practicality of a teaching modules is an important indicator of its feasibility, determining the level of ease and usefulness in practical applications [60], which aligns with Hakiki's [61] assertion that a good teaching modules must exhibit clear characteristics such as attractiveness, comprehensive material, and easy-to-understand language.

The validators (experts and practitioners) have declared the teaching modules valid, and users (students) have found it to be very practical. The next step is to test the teaching modules's effectiveness in training students' critical thinking and collaboration skills. This effectiveness test utilizes the developed assessment tools for critical thinking and collaboration skills, yielding the following findings:

Once validated by both academics and practitioners, and found to be very practical by users (students), the teaching module underwent testing to evaluate its impact on enhancing students' critical thinking and collaboration skills. The findings regarding these skills are detailed in Table 13.

Table 13 shows an increase in critical thinking skills among students. This is reinforced by the N-Gain scores for critical thinking skills of students in schools S01, S02, and S03, which were 0.44, 0.70, and 0.56 respectively, with each N-Gain category falling into the high category for school S02, and moderate category for school S01 and S03. Furthermore, according to Table 13, it can also be noted that there has been an improvement in students' collaboration skills. This is supported by the N-Gain scores for collaboration skills of students at schools S01, S02, and S03, which are 0.52, 0.72, and 0.61 respectively, with each N-Gain category falling into the high category for school S02 and moderate category for school S01 and S03. Based on these findings, it can be concluded that S02 students, who used the teaching modules assisted Computer Vision Integration, achieved higher scores compared to S01 and S03 students.

Table 13. Critical thinking and collaboration skills test result

Skills	School	Pretest	Posttest	N-Gain	Criteria
Critical Thinking	S01	43.31	68.43	0.44	Moderate
	S02	44.44	83,63	0.70	High
	S03	45.55	76.08	0.56	Moderate
Collaboration	S01	64.02	82.77	0.52	Moderate
	S02	69.89	91.76	0.72	High
	S03	62.95	85.86	0.61	Moderate

Furthermore, a two-group test was performed, with the data first undergoing normality and homogeneity tests. The outcomes of the normality tests are displayed in Table 14.

Table 14. Normality test result

Data	Shaphiro-Wilk		
	Statistics	df	Sig.
Pretest_S01_Criticial Thinking	0.891	41	0.001
Pretest_S02_ Criticial Thinking	0.760	41	0.005
Pretest_S03_ Criticial Thinking	0.892	41	0.001
Posttest_S01_Criticial Thinking	0.780	41	0.001
Posttest _S02_ Criticial Thinking	0.651	41	0.001
Posttest _S03_ Criticial Thinking	0.745	41	0.001
Pretest_S01_Collaboration	0.891	41	0.001
Pretest_S01_Collaboration	0.760	41	0.001
Pretest_S01_Collaboration	0.892	41	0.001
Posttest_S01_Collaboration	0.795	41	0.001
Posttest_S01_Collaboration	0.670	41	0.001
Posttest_S01_Collaboration	0.798	41	0.001

According to Table 14, the Sig value is below 0.05, which suggests that the samples in each population group are not normally distributed. Additionally, the homogeneity test results can be found in Table 15.

Table 15. Homogenity test result

Intervention	F	df1	df2	Sig.
Pretest_Critical Thinking	0.015	2	120	0.985
Posttest_Critical Thinking	2.729	2	120	0.069
Pretest_Collaboration	1.682	2	120	0.190
Posttest_Collaboration	1.742	2	120	0.102

The results in Table 15 indicate a Sig value exceeding 0.05, suggesting homogeneity within the sample. However, the normality test confirms the data is not normally distributed ($p < 0.05$). As a result, the Kruskal-Wallis test a non-parametric method was employed to examine differences between the two groups. The findings from this test are detailed in Table 16, generated using SPSS 26.

Table 16 shows a significant difference in media use and its effects on critical thinking and collaboration skills, with a Sig value under 0.05. Additionally, Table 17 presents an Effect Size analysis evaluating the media's impact on critical thinking and multi-representation skills.

Table 16. Kruskall wallis test result

Data	Critical Thingking		Collaboration	
	Pretest	Posttest	Pretest	Posttest
Kruskall-Wallis H	7.756	6.068	9.756	9.908
df	2	2	2	2
Asymp. Sig.	0.041	0.017	0.008	0.007

Table 17. Effect size assesment results

Variables	Eta square	Cohen's f	Interpretation
Critical thinking	0.850	2.380	Strong effect
Collaboration	0.615	1.263	

Table 17 indicates the effect size analysis reveals that the teaching modules assisted by Computer Vision Integration, significantly influences both critical thinking and collaboration skills, with a strong effect size for each.

Based on the N-Gain analysis scores, Kruskall Wallis analysis scores, and effect size analysis scores, it can be said that the Computer Vision Integration (CVI) assisted teaching modules with the PBL model can train students' critical thinking skills. The findings align with research conducted by Mashami [62], Susanti [63], and Oktaviyanti [64], which reinforce that teaching moduless integrated with computer technology in the form of augmented reality media can train students' critical thinking skills. In addition to the use of computer-assisted teaching moduless, the PBL learning model plays a role in supporting the use of teaching moduless to train students' critical thinking skills. The findings in line with research conducted by Sulardi [65], Masrinah [66], and Apriyani [67], who stated that PBL can train students' critical thinking skills, because PBL trains students to solve complex physics problems [68], analyze information, identify assumptions, and formulate hypotheses as they seek solutions to real-world problems [69], and facilitates group discussions that allow students to share ideas and receive feedback, thereby enriching their critical thinking process [70]. In addition to the use of computer-assisted teaching moduless, the PBL learning model has a role in supporting the use of teaching moduless to train students' collaboration skills. The findings of Taryono's research [71] align with this perspective, emphasizing that Problem-Based Learning (PBL) enhances collaboration skills among students. By engaging with real-world problems that necessitate teamwork to solve, students cultivate the ability to work together, exchange ideas, and provide mutual support [72]. The findings from the analysis of students' critical thinking skills align with the scores derived from examining their collaboration skills, as assessed through N-Gain analysis, Kruskall Wallis analysis, and effect size analysis showed that the Computer Vision Integration (CVI) teaching modules with the PBL model can train students' collaboration skills. This is in line with the results of research by Candra [73] and Ginanjar [74], which reinforce that the use of teaching moduless integrated with computer technology in the form of augmented reality media can train students' collaboration skills.

One of the unique aspects of CVI, as used in the Promotrack app, is its ability to provide real-time analysis of experimental data. This allows students to collaboratively test theories and draw conclusions based on data from the experiments conducted, enhancing their critical thinking and analytical skills. In contrast, while AR/VR technology emphasizes the visualization of phenomena and interaction with virtual objects, it lacks a platform for students to analyze experimental data as it happens.

In addition, CVI supports the PBL model in a more direct and data-driven way. In a PBL model integrated with CVI, students can collaborate to analyze experimental results and develop their comprehension of physics concepts. This fosters the development of critical thinking abilities as well as enhanced collaboration skills. AR/VR often focuses more on presenting simulations orvisualizations of physics phenomena, which does not always involve the same analysis of experimental data in terms of its depth and application in real-world problem-solving.

CVI allows students to analyze projectile motion in real time, allowing them to observe live physics phenomena and dynamically analyze experimental data. With this data visualization, students can see the relationship between physics variables such as velocity, launch angle, and distance traveled, which helps improve critical thinking skills. Students not only learn the theory but also testand verify the theory through hands-on experiments. This process trains students to think analytically, formulate hypotheses, and evaluate experimental results based on the data obtained. These findings are align with the previous research conducted by Zhu *et al.* [75], this reasearch explained that computer vision technology could assist students in developing critical thinking skills by allowing them to perform a visual analysis of experimental data in real-time, encouraging active involvement in learning and evaluating the hypotheses proposed. The research conducted by Güney *et al.* [76] supports this notion. Their study indicates that utilizing computer-based learning environments, particularly with technologies like computer vision, enhances students' critical thinking abilities by enabling them to engage in interactive and data-driven experiments.

Furthermore, enhancing students' collaboration skills is another important aspect of CVI's role. In CVI-based hands-on experiments, students work in groups to analyze the generated data, discuss the results, and draw conclusions together, sharing findings and ideas. This technology facilitates active interaction between students, who must collaborate to make sense of complex data and draw conclusions. This collaboration may involve creating experimental designs, choosing pertinent variables, and determining the methods for analyzing and presenting data, all in accordance with the findings of Huang *et al.* [77], this study shows that technologies such as CVI allow students to work together to analyze experimental data and share the results, improving their collaboration skills in an interactive learning environment. In addition, Sung *et al.* [78] showed that computer technology, including CVI, can enhance student collaboration by providing a platform for more effective interaction during technology-based learning activities.

CVI is firmly rooted in the principles of constructivism as outlined by Piaget [79] and Vygotsky [80], asserting that knowledge is developed through direct experiences and interactions with one's surroundings. CVI technology provides an interactive experience that allows students to develop their understanding of physics concepts through visual experimentation and data analysis. CVI also supports experiential learning, where students can conduct live or virtual experiments, view the results, and interpret the data.

This provides opportunities for students to learn from mistakes and try different scenarios to understand physics principles better [81]. According to Kolb [82], engaging in experiential learning fosters a deeper understanding, as it involves students actively participating in their own learning process.

The Computer Vision-assisted modules we developed has great potential for application in various other disciplines and learning contexts. Its success in improving critical thinking skills and collaboration in physics classes demonstrates its benefits. The Promotrack modules, designed to analyze projectile motion, can also be used for other physics topics, such as circular motion or free-fall motion. With Computer Vision technology, students can see real-time visualizations of their experiments, which helps them understand abstract concepts better.

Using Computer Vision technology, students can analyze objects moving in a circular trajectory and understand the concepts of centripetal force, centripetal acceleration, and the relationship between linear velocity and acceleration. Miyake *et al*. [83] shows that utilizing visual technology in science experiments enhances student engagement and deepens the comprehension of challenging physics concepts that may be difficult to understand through theoretical instruction alone.

This modules can provide more accurate and in-depth data related to gravitational acceleration and the concepts of force and mass by utilizing computer vision to analyze free-fall motion. Jansen *et al.* [84] shows that experiments based on visual data allow students to understand better the variables that affect objects' motion under gravity's influence.

In addition to physics, the Promotrack modules has the potential to be applied in sports learning and human body movement analysis. In this field, Computer Vision can analyze athletes' techniques in certain sports, such as running, swimming, or even team sports like football and basketball.

Using Computer Vision to analyze athletes' movements provides greater insight into movement biomechanics, technique, and movement effectiveness insports. Tarr *et al.* [85] revealed that this technology can improve anathlete's technique by providing more accurate data-driven feedback than only visual assessment.

Another area that can benefit significantly from Promotrack is arts education, specifically in graphic design and animation. With Computer Vision's ability to analyze the movement of objects, this modules can teach the basic principles of animation and motion design, where students can learn to explore and create realistic motion animations. Using Computer Vision, students can see how motion animation can be explored more scientifically and structured. Zhao *et al.* [86], shows that the application of computer vision technology in animation design allows students to learn how animation moves more realistically, improving their technical and creative skill.

IV. Conclusion

The research concludes that the teaching modules assisted by Computer Vision Integrationis in the valid category at the validation test stage, with 30 validated items meeting the minimum requirements ($V > 0.75$). This indicates that both experts and practitioners generally agree with the items presented in the instrument. At the practicality test stage, the computer vision integration-assisted teaching modules falls into the very practical criteria, having an average score of 4.48 (89.6%). According to the effectiveness test stage, the teaching module assisted by Computer Vision Integration can train students' ability to work, which is shown by the enhancement in critical thinking and collaboration skills. The acquisition of the n-gain values of critical thinking and collaboration skills reinforces this, where students at school S02 fall into the high criteria, while students at schools S01 and S03 fall into the moderate criteria. Considering the favorable results, we suggest that the CVI-assisted module be implemented more broadly in secondary schools. This would specifically aim to improve essential 21st-century skills, including critical thinking and collaboration. To over come infrastructure limitations, especially in schools with limited facilities, we suggest adapting this modules to simpler devices, such as laptops or computers with minimal specifications, and utilizing open-source software, such as OpenCV, for motion analysis. It is also crucial to ensure that teachers receive training to effectively incorporate this technology into their teaching methods.

We also suggest further research to develop CVI-assisted teaching moduless for other physics topics and conduct cross-cultural trials to understand how these moduless are received and applied in various educational contexts, both inurban and rural areas, with different cultural backgrounds.

This study's findings indicate that secondary schools ought to explore the incorporation of teaching modules that utilize Computer Vision Integration (CVI). Such an approach could significantly improve students' 21st century skills and improve their overall learning experience.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Zulkarnain carried out the research, data analysis, and design. Ni Wayan Sri Darmayanti was in charge of assembling and validating the research instruments. Linda Sekar Utami handled the implementation of the research and development. Moh. Fauzi Bafadal was responsible for the review and editing. All authors contributed to data collection and the writing of the article, and they all reviewed and approved the final manuscript.

Funding

This research was funded by a PFR 2024 research grant from the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia [contract number 110/E5/PG.02.00.PL/2024].

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