

Development of a CinQASE-Based LMS Moodle to Enhance Digital Learning Engagement and Critical Thinking Skills in Work and Energy Concept

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Abstract. Physics learning in secondary schools has not been optimal in fostering critical thinking skills because the concepts are abstract and conventional methods are still dominant. The integration of the CinQASE (Collaborative in Questioning, Analyzing, Synthesizing, Evaluation) model with the Moodle learning management system (LMS) has the potential to provide interactive learning that strengthens digital learning engagement (DLE) and students' critical thinking skills (CTS). Therefore, this study aims to develop a Moodle SMS based on the CinQASE model for work and energy material to improve DLE and critical thinking skills. The research used the 4D development model, which includes the define, design, develop, and disseminate stages, with instruments in the form of validation sheets, teacher and student response questionnaires, critical thinking tests, and DLE activity analysis covering the indicators of questioning, analyzing, synthesizing, evaluating, and discipline. The results showed an expert validation score of 3.72 (highly valid), teacher response of 87% (very practical), and student response of 85% (very practical). The effectiveness test showed an increase in DLE from moderate to high and very high, as well as critical thinking skills with an N-Gain of 0.58 (moderate-high category). Thus, the Moodle LMS based on the CinQASE model for work and energy material is declared valid, practical, and effective as a learning medium to support 21st-century skills.

Keywords: Learning Management System, Moodle, CinQASE, critical thinking, effort and energy

Introduction

Physics education in secondary schools is an important means of fostering students' higher order thinking skills (HOTS), particularly CTS, which are essential for facing the challenges of the 21st century (Fadillah et al., 2024; Kurniawan et al., 2024). However, the reality in the field shows that most students still have difficulty understanding abstract concepts such as work and energy (Irmak et al., 2022; Pramesti et al., 2020). Physics requires not only a mastery of mathematical concepts, but also the ability to relate physical principles to everyday phenomena (Kristiyanto, 2022; Stylos & Kotsis, 2023). This

condition indicates the need for learning innovations that can provide meaningful learning experiences while encouraging students' CTS.

Students' difficulty in understanding the concepts of work and energy is often due to their abstract nature and the need for dual representation skills, both through mathematical equations and visualization of physical phenomena (Rivaldo et al., 2020; Tong et al., 2023). Several studies show that misconceptions are still prevalent, for example, students assume that effort only occurs when there is significant movement or that energy is only related to visible physical activity (Liu & Fang, 2021; Nalkiran & Karamustafaoğlu, 2020). This situation hinders students' ability to relate theory to reality, resulting in learning that is merely the memorization of formulas without a deep conceptual understanding. (Tsivitanidou et al., 2021).

In addition, conventional learning models tend to emphasize solving routine problems without providing sufficient space to hone HOTS (Adnan et al., 2025; Arviani et al., 2023; Zainil et al., 2022). In fact, one of the main objectives of physics education in secondary schools is to develop scientific and critical thinking through contextual problem solving. Without an innovative learning approach, students will find it difficult to develop the analytical, evaluative, and synthetic skills that are indicators of CTS (Anggraeni et al., 2023; Kwangmuang et al., 2021). Therefore, there needs to be a learning strategy that not only conveys concepts, but also actively involves students in the process of discovering and relating these concepts to real-life situations.

In line with this, various constructivist learning approaches have been developed, such as problem based learning (PBL) and metacognition-based models that emphasize students' awareness of their own thinking processes (Arega & Hunde, 2025; Wang et al., 2023). This approach has proven to be more effective in encouraging student engagement, improving conceptual understanding, and reducing misconceptions compared to traditional lecture methods (Ernawati et al., 2023; Kwangmuang et al., 2021). Therefore, physics education needs to apply innovative strategies so that students are trained to think critically, creatively, and are able to solve everyday problems scientifically (Haris et al., 2025; Tunggyshbay et al., 2023).

The use of digital technology, particularly LMS such as moodle, has become a widely used alternative in supporting online and blended learning (Bhadri & Patil, 2022; Bizami et al., 2022; Eryani & Mulyanti, 2021). LMS provides students with the opportunity to access materials, engage in discussions, and complete assignments in a flexible and structured manner. International studies have proven that Moodle is effective in improving student interaction, engagement, and CTS when integrated with the right pedagogical approach (Eraković & Topalov, 2021; Gamage et al., 2022; Peramunugamage et al., 2024). In fact, the application of LMS in science learning has been proven to support metacognitive and collaborative strategies that are essential for the development of science literacy (Adesina, 2023; Ana et al., 2025; Kharismawati, 2024).

Furthermore, recent research confirms that the use of inquiry-based learning and metacognition models can improve students' analytical and problem-solving skills in STEM subjects (Divrik et al., 2021; Ilahi et al., 2024; Rachmi et al., 2025). Meanwhile, the implementation of blended learning with the support of moodle has proven effective in improving critical thinking among secondary school students, particularly in developing countries, including those in Southeast Asia (Indah et al., 2024; Oliveira et al., 2024; Zevender et al., 2024). This shows that the integration of learning technology and innovative pedagogical models can have a positive impact on the quality of learning.

The CinQASE model, which is oriented towards the development of metacognitive skills, offers a systematic approach to training students in asking questions, analyzing problems, synthesizing information, and evaluating solutions. Empirical findings prove that metacognitive model-based strategies in physics learning have a significant effect on students' analytical and evaluative abilities (Muhali & Sukaisih, 2023; Widyaningsih et al., 2024; Winarti et al., 2022). However, studies on the integration of the CinQASE model into

the moodle LMS platform in the context of physics learning, particularly in the subject matter of work and energy, are still very limited.

Based on these conditions, this study aims to develop a moodle LMS based on the CinQASE model as a digital learning space for Physics in grade XI high school. This development focuses on improving students' CTS in the subject of work and energy through the integration of metacognitive strategies in an interactive learning environment. The novelty of this research lies in its attempt to integrate the syntax of the CinQASE model with the moodle LMS in the context of physics learning, which is still rarely done, so that it is expected to make a real contribution to the innovation of science learning at the secondary school level and become a reference for the development of similar digital learning models in the future.

Methods

This study uses a research and development approach with a development model adapted from Borg & Gall's stages, simplified into four main steps, namely: (1) preliminary study, (2) product design, (3) validation and revision, and (4) limited testing. This approach was chosen based on the research objective of producing a product in the form of a CinQASE-based LMS that can be used to improve students' CTS in work and energy.

The research subjects involved tenth-grade high school students as test participants, consisting of two stages. In the limited trial stage, 12 students were purposively selected from a high school in Southeast Sulawesi to obtain initial feedback on the clarity, readability, and ease of use of the product. Furthermore, in the extensive trial phase, there were 30 participants with similar characteristics, so that the data obtained was more representative for testing the effectiveness of the product. In addition to involving students, this study also presented physics experts, ICT-based learning experts, and physics teachers as validators to assess the feasibility of the developed product.

The research instruments consisted of expert validation sheets, student and teacher response questionnaires, CTS tests, and CinQASE online engagement. The validation sheets were used to obtain input from experts on the feasibility of the content, language, appearance, and implementation of the CinQASE-based moodle LMS. The student and teacher response questionnaires were used to determine the level of practicality and acceptance of the developed CinQASE-based LMS by students and teachers. Meanwhile, the CTS test was compiled based on indicators of the ability to question, analyze, synthesize, and evaluate in the context of work and energy material, which was then used to assess the effectiveness of the product. Digital learning engagement was measured using the CinQASE Online Engagement instrument, which was compiled in the form of an online activity rubric. This instrument monitored student participation at each stage of questioning, analyzing, synthesizing, and evaluation in accordance with the CinQASE model flow in the moodle LMS. Student engagement data was collected through discussion forums, task completion, and collaborative interactions. The online activity indicators used are presented in Table 1.

Table 1. CinQASE online engagement indicators

Indicator	Online activity indicator	Description of student activities in moodle LMS
Questioning	Participation in asking questions on the forum	Students ask questions related to the concepts of Work and Energy through the online discussion feature.
Analyzing	Analysis-based problem solving	Students answer data-based or case-based quizzes/exercises on the LMS
Synthesizing	Collaboration in group assignments	Students contribute to compiling reports or joint products on Moodle.

Indicator	Online activity indicator	Description of student activities in moodle LMS
Evaluation	Provide comments or feedback	Students give critical responses to their friends' answers/opinions in discussion forums.
Kedisiplinan online	Consistency in following LMS activities	Students actively log in, participate in activities, and submit assignments on time

The research procedure began with a preliminary study in the form of a needs analysis through interviews with teachers and observations of physics lessons in the classroom. The next stage was product design, which included the design of a CinQASE-based learning system on the moodle platform, covering the integration of questioning, analyzing, synthesizing, and evaluation activities into the LMS structure. After the initial prototype was completed, expert validation was carried out to assess the quality and suitability of the product. Input from the validators was used as the basis for the revision process. Next, limited trials and extensive trials were conducted on 10th grade students to determine the practicality and effectiveness of the product in supporting the improvement of CTS.

The data obtained were analyzed descriptively and inferentially. The expert validation results were analyzed descriptively by converting the scores into feasibility categories. Student and teacher response data were also analyzed descriptively to describe the practicality of the product. Meanwhile, CTS test data were analyzed using a paired t-test to determine the significance of the increase in student scores before and after using the CinQASE-based LMS. Digital learning engagement was measured using the CinQASE Online Engagement instrument, which was compiled in the form of an online activity rubric. This instrument monitors student participation at each stage of questioning, analyzing, synthesizing, and evaluation in each meeting according to the CinQASE model flow in the moodle LMS.

Expert validation was carried out to ensure the feasibility of the developed product in terms of construction with the following sub-aspects: 1) graphic feasibility; 2) feasibility of LMS as e-learning technology. Content aspects with sub-aspects: 1) content feasibility; 2) presentation feasibility; 3) language feasibility. The validation instrument uses a rating scale of 1 to 4, where a score of 1 indicates the category of not feasible and a score of 4 indicates the category of very feasible. This scale is filled in by subject matter experts, ICT-based learning experts, and physics teachers as validators to assess the feasibility of the product. The validation data was analyzed quantitatively through calculations of the mean, percentage, and content validity index (CVI) to determine the agreement between validators. The results were converted into feasibility criteria as a basis for determining product quality. The calculation formula and suitability criteria are presented as follows. The level of agreement between validators is calculated using the CVI formula:

$$CVI = \frac{\sum A}{N} \quad (1)$$

Table 2. Validation result criteria

CVI value	Category
CVI > 0.79	Valid
$0.70 \leq CVI \leq 0.79$	Sufficiently valid
CVI < 0.70	Not valid

(Source: Rodrigues, 2019)

The practicality of the CinQASE based LMS moodle was examined through descriptive analysis of student and teacher responses, with response data scored from 1 to 4. The results of this study provide important information regarding the feasibility of implementing LMS in the learning process. Response data were analyzed using the practicality percentage formula:

$$P = \frac{\sum X}{N \times X_{maks}} \times 100\% \quad (2)$$

Remark:

P : percentage of practicality

$\sum X$: percentage of practicality

N : number of respondents

Xmaks : maximum score per item

The interpretation of the practicality percentage results is presented in Table 3.

Table 3. Practicality interpretation criteria

Practicality test (%)	Interpretation criteria
76-100	Very practical
51-75	Practical
26-50	Enough practical
0-25	Less practical

(Source: Sugiyono, 2015)

The effectiveness of CTS learning was measured to determine the extent of improvement in students' CTS after implementing the moodle LMS based learning model with the CinQASE model. The analysis was conducted using N-gain and paired t-tests.

The effectiveness of learning was measured to determine the extent to which the application of the CinQASE model based on the moodle LMS improved students' CTS and digital engagement. The analysis was conducted using N-gain to assess effectiveness, as well as a paired t-test to determine the significance of the increase in scores.

The improvement in students' CTS was measured through pre-tests and post-tests, then calculated using the N-gain formula:

$$N\text{-Gain} = \frac{\text{Posttest score} - \text{pretest Score}}{\text{Maximum score} - \text{pretest score}} \quad (3)$$

Table 4. Category N-Gain score

N-Gain	Category
≥ 0.7	High
$0.3 \leq N\text{-gain} < 0.7$	Medium
< 0.3	Low

The effectiveness of the CinQASE-based moodle LMS is determined by converting the N-Gain value into a percentage, then comparing it with the classification listed in Table 5.

$$\text{Effectiveness (\%)} = N\text{-Gain} \times 100 \quad (4)$$

Table 5. Effectiveness interpretation criteria

Effectiveness (%)	Interpretation
$E < 0.7$	Ineffective
$40 \leq E < 55$	Less effective
$56 \leq E < 75$	Quite effective
$E \geq 75$	Effective

(Source: Hake, 1999 in Thahura et al., 2024)

The paired t-test was used to determine whether there was a statistically significant difference between the pre-test and post-test scores. This analysis was performed using SPSS version 25. In addition, to assess the level of improvement in learning outcomes, the N-gain score criterion was used, which categorizes student improvement into low, moderate, and high. This N-gain was then used to evaluate the level of improvement in students' CTS after participating in the learning process.

To assess students' digital engagement in each meeting, activities recorded in the moodle LMS were scored based on their level of activity. The assessment scale used was 1 to 5, allowing researchers to see variations in the intensity of student participation in each CinQASE indicator and online discipline. The scores obtained by each student were then summarized and calculated using the following formula:

The total DLE score is calculated as follows:

$$DLE(\%) = \frac{\text{Skor total DLE}}{\text{Skor maximum DLE}} \times 100\% \quad (5)$$

Table 6. Categories of student digital engagement

DLE percentage	Digital engagement category
81-100	Very high
61-80	High
41-60	currently
≤ 40	Moderate

(Source: Sugiono, 2019)

The categorization scheme is used to simplify the results of digital engagement measurements for easier analysis. This approach allows researchers to present their findings in a more structured and standardized manner.

Result and Discussion

The research results are presented based on the 4D development stages, starting from define, design, develop, to disseminate on the CinQASE-based moodle LMS at SMA Negeri 3 Konawe Selatan, Southeast Sulawesi. The presentation includes needs analysis, expert validation, limited trials, and product dissemination, which are then discussed by linking field findings and relevant literature.

Define Stage

The define stage at SMA Negeri 3 Konawe Selatan, through classroom observation and interviews with physics teachers, revealed that students had difficulty relating the concepts of work and energy to everyday phenomena, while the learning process was still teacher-centered, resulting in less active student participation. Student digital engagement and teacher ability to utilize LMS were also limited. Additionally, teachers emphasized the need for a learning model that not only presents material but also encourages students to think critically through questioning, analyzing, synthesizing, and evaluating in accordance with the CinQASE model syntax.

These findings are consistent with previous studies showing that physics learning often faces low student engagement and difficulties in connecting abstract concepts with real-life situations (Bouchée et al., 2021; Zeidan & Young, 2024). Thus, this definition stage confirms the urgent need to provide innovative, practical, and integrated digital learning spaces using the CinQASE model in the moodle LMS.

The findings from observations and interviews at SMA Negeri 3 Konawe Selatan are summarized in Table 1, which shows the conditions, impacts, needs, and related percentages. This presentation highlights the challenges faced by students and teachers and the urgency of developing a CinQASE-based moodle LMS to improve student engagement and critical thinking.

Table 7. Identification of conditions, impacts, and needs in physics learning

Condition	Impact	Requirements	Percentage
Students have difficulty relating the concepts of work and energy to everyday phenomena.	Passive student activity, low comprehension	Contextual learning to understand concepts	68% of students have difficulties
Learning is still teacher-centered	Students lack exploration	Student-centered strategy, stimulation of critical thinking	74% teacher-centered learning
Low digital engagement among students	Minimal participation in digital media	Interactive digital media	30% of students are digitally active
Limited teacher competency in LMS	LMS is suboptimal	Training and guidance on using the CinQASE-based LMS	65% of teachers are limited to LMS
Teachers emphasize models that encourage critical thinking (QASE)	Students' critical thinking is not sufficiently stimulated	CinQASE integrated LMS model	80% of teachers expressed a need

Based on Table 7, it is clear that various obstacles faced by students and teachers require the development of a CinQASE-based moodle LMS that can improve students' digital engagement and CTS.

Design Stage

The design stage was carried out based on a needs analysis in the define stage, with a focus on developing a moodle LMS that fully complies with CinQASE syntax to improve students' digital engagement and CTS through the stages of questioning, analyzing, synthesizing, and evaluating. The design includes the preparation of research instruments (DLE questionnaire, pretest-posttest, and expert validation sheet), LMS outline, feature design (forum, quiz, assignment, progress tracking), and selection of learning media and formats (images, animations, videos, HTML-based web). The LMS outline and features are designed to ensure that the learning process is structured, interactive, and easy to monitor, with attention to content, language, construction, and graphics.

The moodle LMS design refers to Sutopo's (2003) guidelines and the CinQASE model syntax, covering the login page, dashboard, courses, introduction, and core material in accordance with the model. With this design, the LMS is expected to provide a systematic and effective learning experience and to be able to increase digital engagement and critical thinking skills.

Develop Stage

Product Prototype

At this stage, the design phase was implemented into a product in the form of a CinQASE-based moodle LMS for work and energy material. The initial prototype included the integration of CinQASE syntax: (1) Problem orientation, (2) Individual work, (3) collaborative critical thinking, (4) Class discussion, and (5) Evaluation and feedback. This syntax accommodates the indicators of questioning, analyzing, synthesizing, and evaluation, particularly in the collaboration stage through discussion forums, analysis assignments, group synthesis, and self-evaluation and peer evaluation. After the prototype was completed, it was validated by experts to assess the suitability of the content, language, graphics, and e-learning technology. For a clearer picture, the following is a preview of the CinQASE model-based moodle LMS prototype, including various key features that have been developed, based on the CinQASE model syntax as shown in Figures 1 to 6.

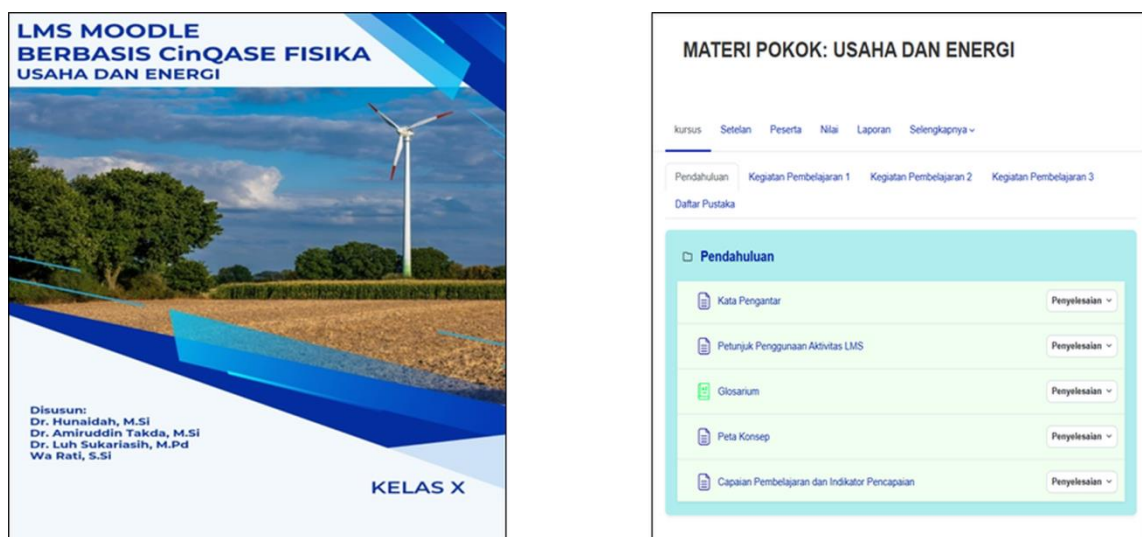


Figure 1. (a) LMS-moodle cover page display based on the CinQASE model, (b) LMS moodle introduction menu structure display

Figure 1 shows the appearance of the home page of the CinQASE-based LMS moodle that was developed. This home page serves as the entrance to learning, containing introductory components such as an introduction, instructions for use, a glossary, a concept map, as well as learning outcomes and achievement indicators.

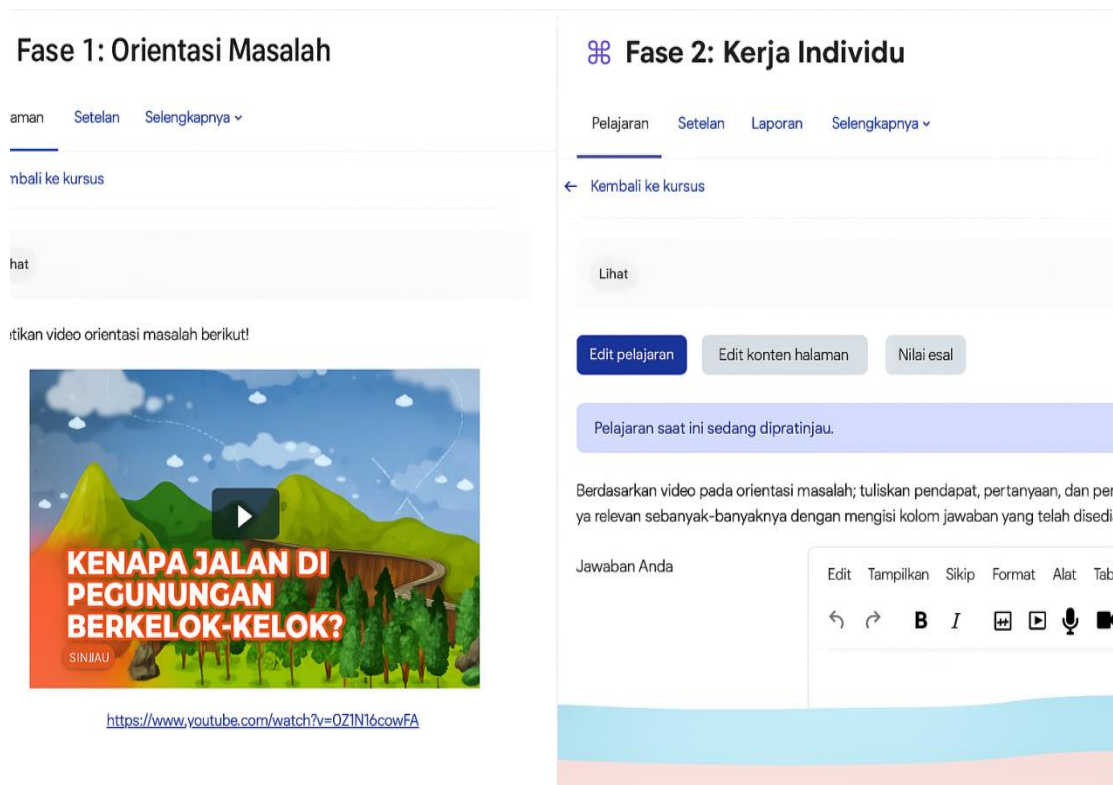


Figure 2. (a) Phase 1 display: problem orientation on moodle LMS, (b) Phase 2 display: individual work on moodle LMS

Figure 2(a) shows the first phase, namely problem orientation, in which students are given stimuli in the form of contextual videos relevant to everyday phenomena. The presentation of these authentic problems aims to arouse curiosity, trigger questions, and direct students to explore the concepts to be learned. Next, Figure 2(b) shows the second phase, Individual Work. At this stage, students are asked to write down their opinions, questions, and personal experiences based on their observations of the problem orientation video. This activity is designed to encourage independent exploration of ideas and practice CTS before entering the collaborative discussion stage.

After students complete the individual work stage, the learning process continues in the collaborative phase. At this stage, students are guided to exchange ideas, test arguments, and build a common understanding through more structured discussions. This collaborative phase consists of two main parts, namely collaborative critical thinking (Phase 3) and class discussion (Phase 4), as shown in Figure 3.

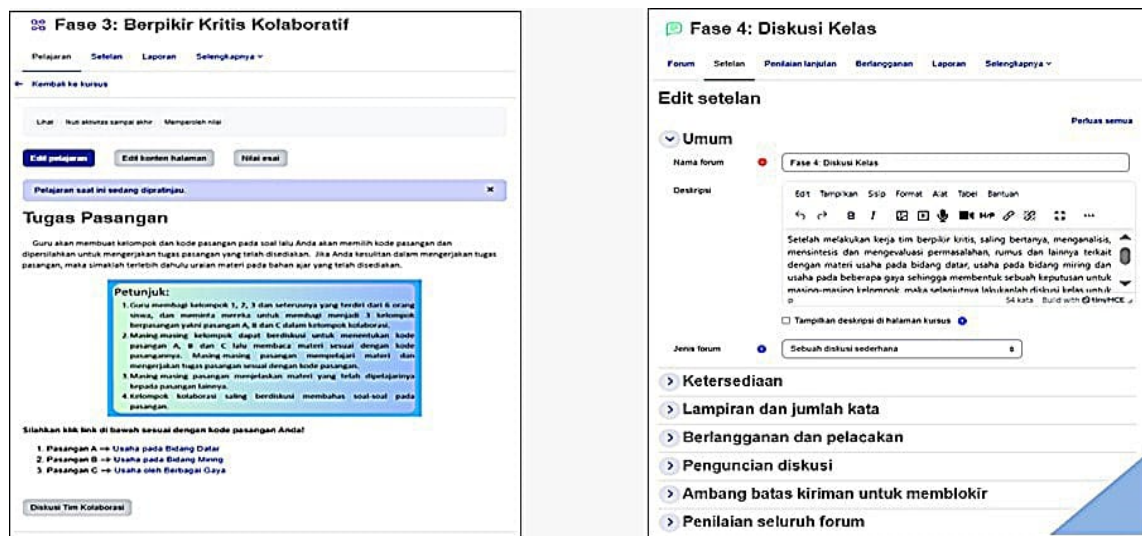


Figure 3. (a) Phase 3: collaborative critical thinking on moodle LMS, (b) Phase 4: class discussion on moodle LMS.

Figure 3a shows the questioning syntax in the CinQASE model. At this stage, students are facilitated to ask critical questions through the discussion forum feature in the Moodle LMS. This activity encourages exploration of initial concepts and builds a foundation of understanding collaboratively. Figure 3b shows the analyzing syntax. Students use quizzes and assignments in moodle to analyze the problems presented. This feature helps students identify patterns, compare information, and strengthen CTS based on the data available in the LMS.

After students participate in learning activities and discussions about work and energy, the next stage in the learning process is to conduct evaluations and self-assessments through the moodle LMS. The following image shows the teacher's evaluation and student self-assessment display on the platform, as shown in Figure 4.

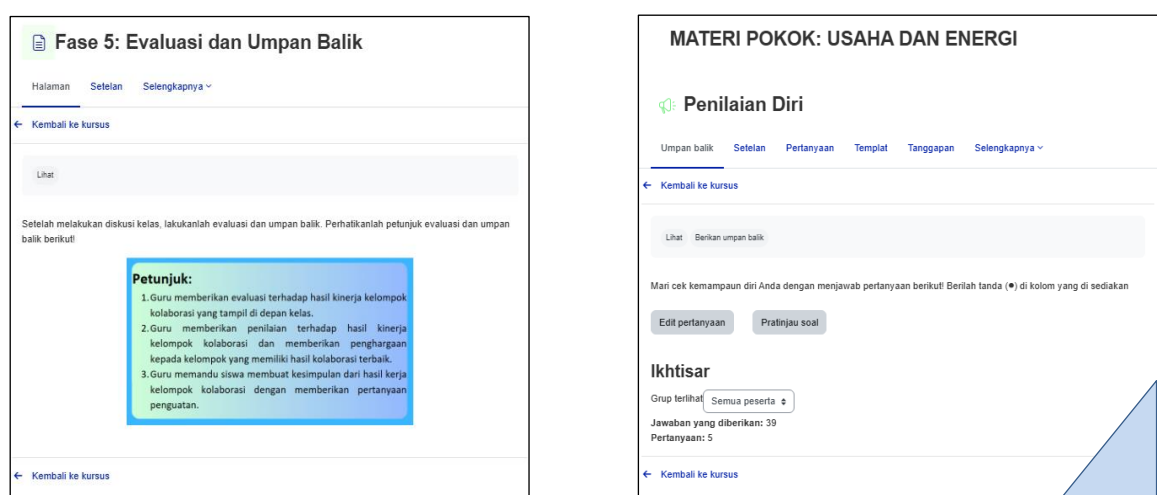


Figure 4. (a) Syntax display 5: evaluation and Feedback on the CinQASE model-based LMS moodle, (b) Self assessment

Figure 4 shows the fifth syntax of the CinQASE model, namely evaluation and feedback. At this stage, teachers play a role in assessing group performance, rewarding the best results, and guiding students to draw conclusions from their learning. This evaluation process not only measures achievement but also provides reinforcement through reflective questions so that students are able to integrate their learning experiences more deeply.

Validity

The CinQASE model-based moodle LMS prototype that was developed was validated by experts to assess the product's suitability from various aspects, namely content/material, language, graphics, and technological suitability. This validation aims to ensure that the product meets quality standards and is ready for use in learning.

The validation results are shown in Table 8. Overall, the prototype obtained an average score of 3.50, which is categorized as Valid, with some aspects obtaining the category of Very Valid, so that the product can be considered suitable for use with some minor recommendations for improvement.

Table 8. Validation results of the CinQASE model-based moodle LMS prototype

Aspects assessed	Assessment indicators	Average score	Category
Content/material	Appropriateness to competencies, completeness of material, accuracy of concepts	3.45	Sufficiently valid
Language	Clarity of language, readability, and appropriateness of terminology	3.60	Valid
Graphics	Interface appearance, design integration, visual appeal	3.40	Sufficiently valid
Technological suitability	Moodle navigation, interactivity, and feature integration	3.55	Valid
Overall average	-	3.50	Sufficiently valid

The validation results in Table 8 show that the CinQASE model-based moodle LMS prototype is feasible for use in learning. The linguistic and technological feasibility aspects were categorized as Very Valid, while the content/material and graphics were categorized as Valid. Several minor improvements, such as interface design refinements, have been noted in the prototype revision.

Disseminate

Practicality of Use

The practicality of the CinQASE-based moodle LMS prototype was analyzed through student and teacher questionnaires and DLE observations. In limited testing, the prototype was tested on a small group of students with teacher assistance. The results showed that the prototype was easy to use, interactive, and supported the stages of questioning, analyzing, synthesizing, and evaluation. The majority of students actively participated, especially in discussion forums and synthesis collaboration, while minor input from students and teachers was used as the basis for revising the prototype.

In field testing, the prototype was applied in several classes or schools. Analysis of questionnaires and DLE observations confirmed that the majority of students and teachers considered the product practical, accessible, and capable of encouraging active engagement in all QASE indicators. These findings show that the practicality of the

prototype is consistent on both a small and large scale, making it suitable for implementation in collaborative STEM learning.

Table 9. Results of the practicality assessment of the moodle CinQASE LMS by teachers and students

Assessment aspect	Indicator	Limited test	Extensive test
Teacher Response (%)	Facilitates critical and systematic thinking	87.5	100
	Facilitates active student participation	75.0	87.5
	Clear activity instructions	87.5	100
	Images facilitate understanding	100	87.5
	Helps identify material concepts	100	87.5
	Easy to implement	75.0	87.5
	Problem orientation encourages learning	100	100
	Clear individual worksheet instructions	87.5	75.0
	Clear collaborative team work instructions	87.5	87.5
	Average	88.9	92.3
Description	-	Very Practical	Very Practical
Student response (Score 1–4)	The LMS interface and navigation are easy to use.	4.0	3.5
	The materials and instructions are easy to understand	3.0	3.5
	The forum encourages questioning	4.0	4.0
	Quizzes/exercises help with analyzing	3.5	3.0
	Collaborative activities increase engagement (synthesizing)	3.5	3.5
	Forum feedback supports evaluation	4.0	3.5
	Improves discipline and motivation to learn	3.5	3.0
	Overall, it helps with critical thinking skills	3.5	4.0
Average	-	3.5	3.5–4.0
Description	-	Very practical	Very practical

Based on Table 8, the assessment results show that the CinQASE-based moodle LMS has a very good level of practicality according to both teachers and students, both in the limited test and extensive test stages. This indicates that the product is practical to use, easy to operate, interactive, and capable of supporting active student engagement in STEM learning based on collaboration and the development of QASE CTS. Thus, this practicality reinforces the feasibility of the LMS for application in physics learning on the subject of work and energy.

Effectiveness

The effectiveness of the CinQASE-based moodle LMS was analyzed to determine the extent to which the use of the prototype could improve students CTS and digital learning engagement in Business and Energy materials. The analysis was conducted through pre-tests and post-tests in limited and extensive trials. The implementation design of the CinQASE-based moodle LMS is presented in Figure 5.

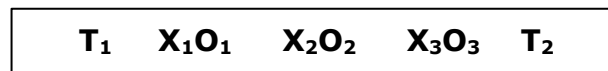


Figure 5. CinQASE-based moodle LMS implementation design

T₁ = CTS pretest

X_iO_{i(1-3)} = Implementation of learning through CinQASE-based LMS model followed by observation of DLE activities from meetings 1-3

T₂ = CTS posttest

Critical Thinking Skills

The graph in Figure 6 presents the N-gain values in the limited trial and extensive trial based on CTS indicators, namely formulating problems, giving arguments, evaluating, and drawing conclusions.

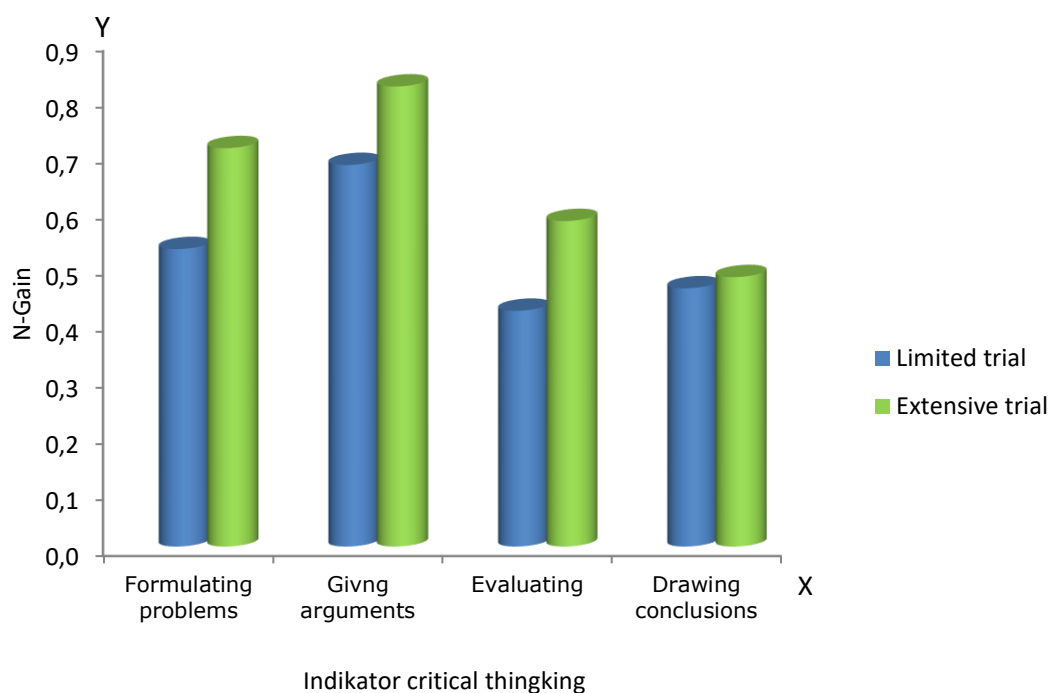


Figure 6. N-Gain values for CTS in limited trials and large-scale trials based on indicators

Based on the graph, it can be seen that the N-gain value in the extensive trial was higher than in the limited trial for almost all CTS indicators. The most notable increase occurred in the giving arguments indicator, while the drawing conclusions indicator showed a relatively small difference between the two trial stages. These results indicate that the

implementation of broader learning can strengthen students' CTS, particularly in the aspect of giving arguments. Thus, these results support the findings of other studies that the implementation of collaborative and critical thinking-based learning can significantly improve the quality of students' cognitive skills. (Hasanah et al., 2021; Yasir & Dwiyantri, 2023).

To provide a more detailed picture of these achievements, Table 9 below presents the pretest and posttest results, N-gain scores (<g>), and categories of improvement in students' CTS for each indicator in the limited trial and large-scale trial.

Table 10. Results of CTS assessment in limited trials and large-scale trials

Critical thinking indicators	Limited trial						Extensive trials					
	Pretest value	Posttest value	<g>	Category	E %	Interpretation	Pretest value	Posttest value	<g>	Category	E%	Interpretation
Formulating the problem	55	80	0,53	medium	53	Less effective	43	83	0,76	high	76	Effective
Providing arguments	48	82	0,68	medium	68	Quite effective	35	89	0,82	high	82	Effective
Evaluating	44	60	0,42	medium	42	Less effective	34	76	0,70	medium	58	Quite Effective
Drawing conclusions	50	69	0,46	medium	46	Less effective	34	88	0,81	high	80	Effective

to be higher than in the limited trial. In the indicators of formulating the problem, providing arguments, and drawing conclusions, the increase was in the high category with N-gains of 0.76, 0.82, and 0.80, respectively, and was classified as effective. Meanwhile, the evaluate indicator is still in the moderate category even though the N-gain value and its effectiveness increased from the limited trial to the large-scale trial. These findings indicate that learning on a larger scale can have a more significant impact, especially on the ability to formulate problems, provide arguments, and draw conclusions, although the evaluation aspect still needs further strengthening. In addition to being reviewed from each CTS indicator, the results of the limited trial and large-scale trial can also be seen as a whole through descriptive pre-test and post-test data. Details of the lowest score, highest score, average, standard deviation, and number of students at each trial stage are presented in Table 10.

Table 11. Description of pre-test and post-test scores for critical thinking limited trial and extensive trial

	Limited trial		Extensive trials	
	<i>Pre-test</i>	<i>Post-test</i>	<i>Pre-test</i>	<i>Post-test</i>
Minimum value	29	43	14	57
Maksimal value	80	100	67	100
Average	49.14	72.66	38.25	83.25
standard deviation	13.49	15.47	14.05	11.72
Ideal value	100	100	100	100
Number of students	12	12	29	29

Based on Table 11, it can be seen that in the limited trial, the average pre-test score of 49.14 increased to 72.66 in the post-test, while in the large-scale trial, the average pre-test score of 38.25 increased even higher to 83.25 in the post-test. The lowest scores in

both trial stages also increased significantly, from 29 to 43 in the limited trial and from 14 to 57 in the large-scale trial. In addition, the standard deviation in the large-scale trial decreased from 14.05 to 11.72, indicating that the learning outcomes of the students tended to be more evenly distributed after the treatment. These results indicate that the treatment was not only effective in increasing the average score but also in improving the evenness of student achievement, in line with the findings of similar studies (Lazuardi et al., 2023; Manik & Wulandari, 2023). This also indicates that the implementation of learning not only improves average achievement, but is also able to reduce the gap in results between students.

Before conducting further analysis, a normality test was first performed to ensure that the pre-test and post-test data in both the limited trial and the extensive trial were normally distributed. The results of the normality test are presented in Table 12.

Table 12. Results of normality tests for pre-test and post-test CTS limited trials and extensive trials

Data	Statistic	Sig.	Description
Pre-test results of limited trials	0.993	0.971	Normally
Post-test results of limited trials	0.913	0.497	Normally
Pre-test results of field trials	0.912	0.492	Normally
Post-test results of field trials	0.968	0.827	Normally

Based on the results of the normality test, the pre-test and post-test data in both the limited trial and the extensive trial showed a normal distribution ($p > 0.05$). Thus, the analysis can be continued using parametric tests to test the research hypothesis.

After confirming normal distribution, the data was further analyzed using a t-test to examine the consistency of the impact of implementing Moodle LMS in improving CTS in limited trials and extensive trials. The results of the analysis are shown in Table 13.

Table 13. Results of levene's test and t-test for equality of means

		Levene's Test for of Equality of Variances			t-test for Equality of Means				
Data		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference
									Lower Upper
Data	Equal variances assumed			-1.133	6	0.231	-0.12500	0.09379	-0.35449 0.10449
	Equal variances not assumed	0.636	0.455	-1.133	5.632	0.234	-0.12500	0.09379	-0.35818 0.10818

The t-test results show that the significance value (Sig. 2-tailed) is greater than 0.05, so there is no significant difference between the limited trial and the extensive trial. These findings indicate the consistency of the impact of implementing the moodle LMS in improving students' CTS, both in the limited trial and extensive trial stages.

Digital Learning Engagement

To determine digital learning engagement, measurements were taken on five key indicators, namely questioning, analyzing, synthesizing, evaluating, and discipline, through three learning sessions. The data from the observations of each indicator in each session are shown in Table 14.

Table 14. DLE indicator observation results per session

DLE Indicator	Value (%)	Category	Value	Category	Value	Category
Questioning	46.0	currently	79.0	High	85.0	Very high
Analizing	34.0	Low	65.0	High	76.4	High
Sintesizing	31.6	Low	68.0	High	73.4	High
Evaluating	41.6	currently	61.6	High	71.2	High
DIscipline	54.4	Currently	73.0	High	82.0	Very high

Based on Table 14, it can be seen that digital learning engagement increased across all indicators from the first session to the third session. In the Questioning indicator, student engagement increased from the moderate category (46.0%) in session 1 to high (79.0%) in session 2, and reached the very high category (85.0%) in session 3. The analyzing and synthesizing indicators, which were initially in the low category (34.0% and 31.6%) in session 1, showed consistent increases to reach the high category in sessions 2 and 3 (76.4% and 73.4%). The evaluating indicator also shifted from the moderate category (41.6%) in session 1 to high in sessions 2 and 3 (61.6% and 71.2%). Meanwhile, the Discipline indicator showed relatively better initial results compared to other indicators, namely the medium category (54.4%), then increased to high in session 2 (73.0%) and reached the very high category (82.0%) in session 3.

To clarify the upward trend shown in Table 13, the data was then visualized in a bar chart in Figure 7.

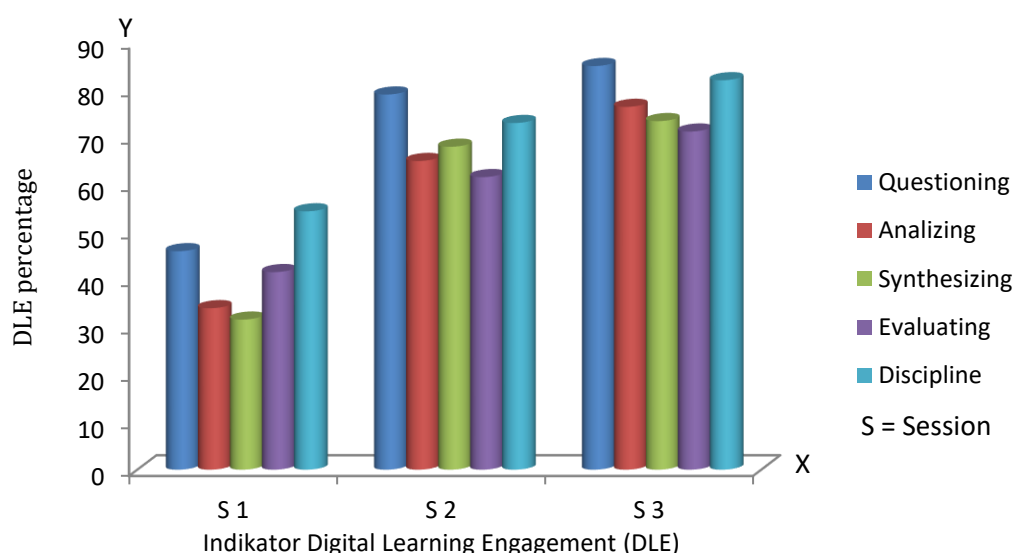
**Figure 7.** Development of DLE indicators in three learning sessions

Figure 7 shows the development of students' digital learning engagement in five key indicators during three learning sessions. In general, the graph shows a consistent upward trend in all indicators. In the first session, the discipline indicator ranked highest compared to other indicators, while Synthesizing ranked lowest. Entering the second session, all indicators experienced a significant increase, with Questioning and Discipline being the two most prominent indicators. In the third session, engagement levels strengthened further,

with Questioning reaching the highest score of nearly 90%, while other indicators such as Analyzing, Synthesizing, Evaluating, and Discipline continued to show steady improvement. Overall, the results in Table 12 and Figure 7 confirm that student engagement in digital learning developed progressively in terms of cognitive, affective, and learning discipline aspects as the learning sessions progressed.

Conclusion

The CinQASE model-based moodle LMS has been proven effective in improving students' CTS and DLE in physics education. The integration of the CinQASE model with the moodle LMS provides interactive learning that overcomes the limitations of conventional methods in teaching abstract concepts. This development shows real potential as a solution for fostering 21st-century skills in secondary schools and serves as a reference for similar digital learning models.

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References

- Adesina, A. (2023). Enhancing Science Education with Learning Management System for Effective Learning Outcomes. *Qeios*. <https://doi.org/10.32388/vurdu1>
- Adnan, A., Saenab, S., Rahmatullah, R., Almunawarah, R., & Sahira, S. (2025). The Effect of Citizen Science Project Learning Model on Students' Critical and Creative Thinking Skills. *International Journal of Cognitive Research in Science, Engineering and Education*. <https://doi.org/10.23947/2334-8496-2025-13-1-51-61>
- Ana, F., Adnan, A., & Azis, A.A. (2025). The Effect of Blended Learning (Individual Rotate, Flex, and Inside-Out) on Digital Literacy Skills in Science Learning. *Jurnal Eduscience*. <https://doi.org/10.36987/jes.v12i2.7084>
- Anggraeni, D., Prahani, B., Suprpto, N., Shofiyah, N., & Jatmiko, B. (2023). Systematic Review of Problem Based Learning Research in Fostering Critical Thinking Skills. *Thinking Skills and Creativity*. <https://doi.org/10.1016/j.tsc.2023.101334>
- Arega, N.T., & Hunde, T. (2025). Constructivist instructional approaches: A systematic review of evaluation-based evidence for effectiveness. *Review of Education*. <https://doi.org/10.1002/rev3.70040>
- Arviani, F.P., Wahyudin, D., & Dewi, L. (2023). The Effectiveness of Problem Based Learning Model in Improving Students' Higher Order Thinking Skills. *JPI (Jurnal Pendidikan Indonesia)*. <https://doi.org/10.23887/jpiundiksha.v12i4.65606>
- Bhadri, G., & Patil, L. (2022). Blended Learning: An effective approach for Online Teaching and Learning. *Journal of Engineering Education Transformations*. <https://doi.org/10.16920/jeet/2022/v35is1/22008>

- Bizami, N.A., Tasir, Z., & Kew, S. (2022). Innovative pedagogical principles and technological tools capabilities for immersive blended learning: a systematic literature review. *Education and Information Technologies*, 28, 1373–1425. <https://doi.org/10.1007/s10639-022-11243-w>
- Bouchée, T., De Putter - Smits, L., Thurlings, M., & Pepin, B. (2021). Towards a better understanding of conceptual difficulties in introductory quantum physics courses. *Studies in Science Education*, 58, 183–202. <https://doi.org/10.1080/03057267.2021.1963579>
- Divrik, R., Piltan, P., & Taş, A. (2021). Effect of Inquiry-Based Learning Method Supported by Metacognitive Strategies on Fourth-Grade Students Problem-Solving and Problem-Posing Skills: A Mixed Methods Research. *International Electronic Journal of Elementary Education*. <https://doi.org/10.26822/IEJEE.2021.191>
- Eraković, B., & Topalov, J. (2021). Teaching and learning through Moodle, Google Doc and Zoom: Fostering student engagement in (a)synchronous learning environments. *Inovacije u Nastavi*. <https://doi.org/10.5937/inovacije2104122e>
- Ernawati, M.D.W., Sudarmin, S., Asrial, A., & Haryanto, H. (2023). The Effect of Scaffolding-Based Problem-Based Learning on Creative Thinking Skills on Hormone Materials. *Jurnal Pendidikan Sains Indonesia*, 11(1), 129–141. <https://doi.org/10.24815/jpsi.v11i1.26955>
- Eryani, Y., & Mulyanti, B. (2021). Technology-based blended learning to accommodate offline and online learning. *IOP Conference Series: Materials Science and Engineering*, 1098. <https://doi.org/10.1088/1757-899X/1098/3/032010>
- Fadillah, M. A., Usmeldi, U., & Asrizal, A. (2024). The Role of Chatgpt And Higher-Order Thinking Skills As Predictors of Physics Inquiry. *Journal of Baltic Science Education*. <https://doi.org/10.33225/jbse/24.23.1178>
- Gamage, S., Ayres, J., & Behrend, M. (2022). A systematic review on trends in using Moodle for teaching and learning. *International Journal of Stem Education*, 9. <https://doi.org/10.1186/s40594-021-00323-x>
- Haris, A., Hasyim, M., Ma'ruf, Halim, A. D., Mahir, & Ramadhan, I. (2025). The Effectiveness of Dynamic Problem-Solving Strategy and Innovative Assessment Tools to Improve Students' Higher-Order Thinking Skills. *Jurnal Pendidikan IPA Indonesia*. <https://doi.org/10.15294/jpii.v14i1.21433>
- Hasanah, Z., Pada, A.U.T., Safrida, S., Artika, W., & Mudatsir, M. (2021). Implementasi Model Problem Based Learning Dipadu LKPD Berbasis STEM untuk Meningkatkan Keterampilan Berpikir Kritis pada Materi Pencemaran Lingkungan. *Jurnal Pendidikan Sains Indonesia*, 9(1), 65–75. <https://doi.org/10.24815/jpsi.v9i1.18134>
- Ilahi, D.P., Festiyed, Yerimadesi, Yulkifli, Utami, L., & Ratih, A. (2024). Evaluating the Impact of Problem Based Learning on Student's Metacognition in Science Learning: A Meta-Analysis Review. *Jurnal Penelitian Pendidikan IPA*. <https://doi.org/10.29303/jppipa.v10i8.7892>
- Indah, R., Rakhmawati, D.E.N., & Umami, H.A. (2024). Does Blended Learning Reshape Students' Critical Thinking Skills? An Evaluative Study of Indonesian Learners. *World Journal of English Language*. <https://doi.org/10.5430/wjel.v14n5p444>

- Irmak, M., İnaltun, H., Ercan-Dursun, J., Yanış-Kelleci, H., & Yürük, N. (2022). Development and Application of a Three-Tier Diagnostic Test to Assess Pre-service Science Teachers' Understanding on Work-Power and Energy Concepts. *International Journal of Science and Mathematics Education*, 21, 159–185. <https://doi.org/10.1007/s10763-021-10242-6>
- Kharismawati, I. (2024). Effectiveness of Collaborative Learning Using an Artificial Intelligence-Based Learning Management System (LMS) to Enhance Scientific Literacy Skill for Early Childhood Education Teacher Candidates. *Pakistan Journal of Life and Social Sciences (PJLSS)*. <https://doi.org/10.57239/pjlss-2024-22.2.001238>
- Kristiyanto, W.H. (2022). Teaching Physics in Scientific Information Disclosure Era Through Daily Physics Learning. *Journal of Physics: Conference Series*, 2392. <https://doi.org/10.1088/1742-6596/2392/1/012028>
- Kurniawan, E.S., Mundilarto, M., & Istiyono, E. (2024). Improving student higher order thinking skills using SynecticHOTS-oriented learning model. *International Journal of Evaluation and Research in Education (IJERE)*. <https://doi.org/10.11591/ijere.v13i2.25002>
- Kwangmuang, P., Jarutkamolpong, S., Sangboonraung, W., & Daungtod, S. (2021). The development of learning innovation to enhance higher order thinking skills for students in Thailand junior high schools. *Heliyon*, 7. <https://doi.org/10.1016/j.heliyon.2021.e07309>
- Lazuardi, M.A., Haryandi, S., & Ibrahim, M. (2023). The Effectiveness of Electronic Modules on Problem-Solving Oriented Work and Energy Topics to Improve Student Learning Outcomes. *Jurnal Ilmiah Pendidikan Fisika*. <https://doi.org/10.20527/jipf.v7i1.7311>
- Liu, G., & Fang, N. (2021). The effects of enhanced hands-on experimentation on correcting student misconceptions about work and energy in engineering mechanics. *Research in Science & Technological Education*, 41, 462–481. <https://doi.org/10.1080/02635143.2021.1909555>
- Manik, L.K., & Wulandari, D. (2023). The Development of E-Module Based on Scientific Approach to Improve Student Learning Outcomes in Work and Energy Materials. *IPER (Indonesian Physics Education Research)*. <https://doi.org/10.24114/iper.v4i1.63099>
- Muhali, M., & Sukaisih, R. (2023). Guided Discovery Learning Model Using Concept Map Strategy to Improve Students Metacognition and Critical Thinking Skills. *Jurnal Penelitian Pendidikan IPA*. <https://doi.org/10.29303/jppipa.v9i1.3868>
- Nalkiran, T., & Karamustafaoğlu, S. (2020). Prediction-Observation-Explanation (POE) Method and Its Efficiency in Teaching "Work, Energy, Power" Concepts. *International Journal of Assessment Tools in Education*, 7, 497–521.
- Oliveira, G., Fernandes, M., Maissiat, J., & Costa, N. (2024). Comprehensive Analysis of Moodle Activity Recommendations considering Complex Thinking Theory for Enhancing Learning Outcomes. *Anais Do XXXV Simpósio Brasileiro de Informática Na Educação (SBIE 2024)*. <https://doi.org/10.5753/sbie.2024.242666>
- Peramunugamage, A., Ratnayake, U., Karunanayaka, S., & Jayawardena, C. (2024). Design of Moodle-based collaborative learning activities to enhance student interactions. *Asian Association of Open Universities Journal*. <https://doi.org/10.1108/aaouj-06-2023-0079>

- Pramesti, Y., Mahmudi, H., & Setyowidodo, I. (2020). Analyzing Students' Understanding of Work-Energy Concept. *Journal of Physics: Conference Series*, 1521. <https://doi.org/10.1088/1742-6596/1521/2/022016>
- Rachmi, C.N., Jupri, A., Juandi, D., & Bulubaan, S. (2025). Research Exploration of Problem-Based Learning (PBL) Model and Metacognition Ability in Mathematics Learning: A Systematic Literature Review. *Jurnal Pendidikan MIPA*. <https://doi.org/10.23960/jpmipa.v26i1.pp227-243>
- Rivaldo, L., Taqwa, M., Zainuddin, A., & Faizah, R. (2020). Analysis of Students' Difficulties About Work And Energy. *Journal of Physics: Conference Series*, 1567. <https://doi.org/10.1088/1742-6596/1567/3/032088>
- Rodrigues, I., Adachi, J., Beattie, K., Lau, A., & Macdermid, J. (2019). Determining Known-Group Validity And Test-Retest Reliability in the PEQ (personalized exercise questionnaire). *BMC Musculoskeletal Disorders*, 20. <https://doi.org/10.1186/s12891-019-2761-3>
- Stylos, G., & Kotsis, K. (2023). Undergraduate physics students' understanding of thermal phenomena in everyday life. *Contemporary Mathematics and Science Education*. <https://doi.org/10.30935/conmaths/13406>
- Thahura, L., Lodang, H., & Saleh, A.R. (2024). Keefektifan Pendekatan Joyfull Learning Berbasis Ice Breaking Untuk Meningkatkan Hasil Belajar Biologi Tentang Materi Substansi Genetik Pada SMA Kelas XII. *Oryza (Jurnal Pendidikan Biologi)*, 13(1), 116–127. <https://doi.org/10.33627/oz.v13i1.1828>
- Tong, D., Liu, J., Sun, Y., Liu, Q., Zhang, X., Pan, S., & Bao, L. (2023). Assessment of student knowledge integration in learning work and mechanical energy. *Physical Review Physics Education Research*. <https://doi.org/10.1103/physrevphyseducres.19.010127>
- Tsivitanidou, O., Georgiou, Y., & Ioannou, A. (2021). A Learning Experience in Inquiry-Based Physics with Immersive Virtual Reality: Student Perceptions and an Interaction Effect Between Conceptual Gains and Attitudinal Profiles. *Journal of Science Education and Technology*, 30, 841–861. <https://doi.org/10.1007/s10956-021-09924-1>
- Tunggyshbay, M., Balta, N., & Admiraal, W. (2023). Flipped classroom strategies and innovative teaching approaches in physics education: A systematic review. *Eurasia Journal of Mathematics, Science and Technology Education*. <https://doi.org/10.29333/ejmste/13258>
- Wang, S., Kong, X., & Lv, J. (2023). Visualization of Complex Mechanics Problems Using Finite Element Technique for Enhancing Problem-based Learning Instruction. *Proceedings of the 7th International Conference on Digital Technology in Education*. <https://doi.org/10.1145/3626686.3626697>
- Widyaningsih, S., Kuswandi, D., Aulia, F., Yusro, A., & Yusuf, I. (2024). Problem-Based Learning to Metacognition in Physics Learning in Indonesia: Literature Review. *Jurnal Ilmiah Pendidikan Fisika*. <https://doi.org/10.20527/jipf.v8i1.11141>
- Winarti, W., Ambaryani, S.E., & Putranta, H. (2022). Improving Learners' Metacognitive Skills with Self-Regulated Learning based Problem-Solving. *International Journal of Instruction*. <https://doi.org/10.29333/iji.2022.1528a>

- Yasir, M., & Dwiyantri, L. (2023). Analysis of Critical Thinking Levels of Prospective Science Teachers in Ethnoscience Learning Based on Reflective and Impulsive Cognitive Styles. *Jurnal Pendidikan Sains Indonesia*, 11(4), 808–825. <https://doi.org/10.24815/jpsi.v11i4.31799>
- Zainil, M., Kenedi, A. K., Rahmatina, Indrawati, T., & Handrianto, C. (2022). The Influence of a STEM-Based Digital Classroom Learning Model and High-Order Thinking Skills on the 21st-Century Skills of Elementary School Students in Indonesia. *Journal of Education and E-Learning Research*. <https://doi.org/10.20448/jeelr.v10i1.4336>
- Zeidan, M., & Young, D. (2024). Enhancing Classroom Engagement: Investigating Student Motivation towards Learning Physics. *Schrödinger: Journal of Physics Education*. <https://doi.org/10.37251/sjpe.v5i4.1288>
- Zevender, P., Disman, D., Mulyadi, H., Mardetini, E., Adriani, D., & Hakam, L. I. (2024). Learning model development moodle-based problem-based learning to improve critical thinking ability. *JPPI (Jurnal Penelitian Pendidikan Indonesia)*. <https://doi.org/10.29210/020242982>