Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 8, No. 6, 8682-8695
2024
Publisher: Learning Gate
DOI: 10.55214/25768484.v8i6.3856

Evaluation of model mind mapping science blended to enhance students students' critical thinking skills

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Abstract: This research examines how practicality and effective the integration of the MOODLE system with Mind Mapping Science is in enhancing students' critical thinking skills (CTS). A sample of 127 students from three Indonesian universities was chosen through cluster sampling, and the researchers employed a single-group pre-test-post-test experimental design. Various tools such as CTS assessments, surveys, and observation checklists were utilized in this study. The findings indicate that the combination of the MOODLE-based MMSB model is both effective and efficient. The analysis process involved determining the mean score, conducting a paired t-test, calculating the N-gain value, and evaluating questionnaire feedback on the implementation of the MOODLE-based MMSB model. Each of these steps demonstrated reliability, meeting the "very good" standard and confirming its practicality. The effectiveness of the model is highlighted by a significant increase in CTS scores at a 5% significance level. The average N-gain results were consistent across different classes at each university. Student feedback was very effective, indicating a strong interest in applying this model. In conclusion, the results suggest that combining the MOODLE system with the MMSB model leads to improved CTS and greatly supports structured learning processes in various disciplines.
Keywords: *Critical thinking ability, Mind mapping science blended, MOODLE; Effectiveness, Practicality.*

1. Introduction

By 2025, it's unknown if employment norms will change [1], but CTS will change to adapt to the trends of the industrial revolution and be incorporated into different industrial cyberphysical systems (CPS) [2], [3], and [4]. Training CTS to students in university is very important because students are agents of change in society. By practicing CTS with students, they can have the skills to deal with the issue that occur in everyday life. Other than that, ICT has an impact on training and education, two crucial aspects of this sector. For scientists, educators, and students, the emergence of Internet of Things technology has presented both new opportunities and challenges [5]. Numerous industries have changed and operating expenses have decreased due to automation and easy access to resources [6], [7]. Digital technology has totally taken over the educational landscape, and blended learning also referred to as fully digital mixed learning has supplanted the conventional face-to-face interaction model [8], [9]. Furthermore, the education industry has been greatly impacted by the transition to digital technology [7], [10], with online learning emerging as a crucial component of the contemporary educational system [11], [12], and [13]. In order to manage digital learning experiences and provide educational materials, MOODLE and its kind of Learning Management System (LMS) are essential [14], [15], and [16].

MOODLE's open source capabilities, versatility, and its popularity stems from its ease of usage tool for facilitating student collaboration, and communication [17], [18], and [19]. The importance of technology-based creative learning approaches is demonstrated by the use of MOODLE in digital learning [20]. An increasingly popular pedagogical strategy in higher education is problem-based learning (PBL), which teaches students to think critically, work together, solve issues, and learn on their

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own. The environment, both physical and socio-cultural, can make a specific. This is due to the fact that problem-based learning forces students to handle issues and circumstances that arise in the real world [23], [24], and [25]. According to Rahmadita et al. (2021), PBL scenarios allow students to show that they can construct solutions and form conclusions. Because mind mapping enables the generation of new information through adaptation and assimilation of old knowledge, it is a useful strategy to overcome developmental impediments to CTS [23]. Additionally, it can support students in developing a methodical approach to thinking, making connections between ideas, and coming to conclusions [27], [28], and [29].

Although the MOODLE platform is not yet completely integrated with mind mapping, it has a lot of promise to enhance CTS. One of the universities in Cluster II (Certification B) conducted the first experiment in two courses. According to preliminary testing results, the MOODLE-based MMSB teaching paradigm can raise students' CTS and is legitimate, useful, and successful. Consequently, more experiments are required to create a MOODLE-based MMSB teaching paradigm.

Thus, the focus of this study is on CTS development and mixed scientific learning. A creative model for a digital learning platform that included mind maps with MOODLE was started and assessed. It may be possible to promote CTS in science education, particularly physics, by using this MOODLE-based MMSB paradigm. It can also help change the educational environment and supply students with the knowledge and abilities they need to thrive in the contemporary world. The six organized steps of this model are orientation, organization, investigation, developing mind mapping, create & present the work, and evaluate. This study [30] used particular standards of analysis, interpretation, inference, and assessment to ascertain whether the MMSB model is successful in raising students' CTS. Thus, the researcher came up with the following query: How can the MOODLE-based MMSB model be considered as practice and effective in increasing students' CTS?

2. Objective

2.1. MOODLE-Based MMSB Learning Model

A Science Blended Mind Mapping (MMSB) learning paradigm based on MOODLE was developed in response to empirical and theoretical study on the limitations of using the PBL approach to raise students' CTS. The MOODLE-based MMSB approach integrates direct (synchronous) and independent (asynchronous) learning with MOODLE-based learning. With this methodology, learning can take place both in-person and virtually using the MOODLE Learning Management System (LMS), which both teachers and students can access from any location at any time.

According to the findings of the PBL learning model study, critical thinking indicators that cannot be trained using the PBL model cannot be learned, despite the fact that the PBL model is applied to boost student engagement. Thus, creating a MOODLE-based MMSB model is the best course of action for training CTS indicators specifically, inference indicators which are still lacking. One step is to use mind maps. Students' learning and CTS can both be enhanced by mind mapping. They benefit from it in a variety of ways, including planning, communicating, being more creative, solving issues, focusing, organizing and elucidating their thoughts, improving memory function, learning more quickly and efficiently, and receiving instruction to fully explain concepts [31].

Students can use mind mapping as a learning tool to solve issues, arrange ideas, enhance memory, exchange ideas, and tell tales. Additionally, kids are able to draw conclusions, generalize, and demonstrate connections between different topics. [32]. Since mind images are a powerful tool for promoting organizational thinking, they promote the sharing and exploration of information outside the confines of the brain [33]. There are six learning syntaxes that teach CTS indicators for model training. Table 1 displays information regarding the model syntax and indicators trained for every MOODLE-based MMSB model syntax.

Table 1.
Syntax of MOODLE-based MMSB learning model and CTS indicators trained.

Syntax model	**Activity**	**CTS indicators Trained**
Level 1 0rientation	Lecturer activities:	Interpretation
	1. The lecturer conveys the learning objectives	
	2. Lecturers encourage students to participate actively in both in-person and online learning.	
	3. The lecturer gives problems to be solved in groups. MOODLE provides access to issues online.	
	Student activities:	
	1. Students listen to the lecturer's presentation	
	2. Students practice in groups to identify learning accessed in MOODLE	
	3. Students in groups open MOODLE, then take note of and comprehend the issues raised by the instructor or gleaned from the readings recommended in the MOODLE link.	
Level 2 organization	Lecturer activities:	Analysis
	1. Lecturers ensure ensure each participant is aware of their specific responsibilities	
	Student activities:	
	1. Students collaborate and split tasks to find the information, resources, and equipment needed to solve the problem. The discussions were held in person and recorded online using MOODLE.	
Phase 3 investigation	Lecturer activities:	Interpretation Analaysis Inference
	1. Lecturers monitor student participation in gathering information and materials for the investigation	
	Student activities:	
	1. In order to gather information for group discussions, students do investigations (look for facts, references, and sources). Face-to-face discussions were conducted by looking at online resources in MOODLE.	
Phase 4 developing mind mapping	Lecturer activities:	Inference
	1. The lecturer directs each group to create *mind mapping* from the data obtained to answer the given problem	
	Student activities:	
	1. Students arrange in groups *mind mapping* from the data obtained to solve the given problem. *Mind mapping* created based on the results of discussions and uploaded to MOODLE	
Phase 5 Create and present the work	Lecturer activities:	Inference Evaluation
	1. To ensure that each group's work is prepared for presentation, the lecturer oversees the conversation and provides guidance during report preparation.	

Syntax model	Activity	CTS indicators Trained
	Student activities:	
	1. Based on information gathered from creating mind maps, the group conducts discussions to generate answers to problems, which are then presented as work. The outcomes of in-person conversations are posted on MOODLE.	
Phase 6 evaluation	Lecturer activities:	Evaluation
	1. The lecturer guides the presentation and encourages organizations to provide other organizations with awards and feedback.	
	2. The lecturer and students wrap up the content.	
	Student activities:	
	1. After each group presents, the other groups express gratitude.	
	2. Students and lecturers draw inferences from information gathered from other organizations. The group discussion's outcomes and conclusions are posted on MOODLE via a link.	

2.2. Critical Thinking Skills (CTS)

CTS is a crucial talent that kids need to develop in today's classroom in order to be flexible. Some people frequently refer to advanced process skills as CTS. Students with these excellent processing skills can refine information from multiple sources and experiences and integrate their knowledge to obtain a more comprehensive perspective. Critical thinking requires several complex cognitive abilities [35] and [36], such as a blend of expertise, cognitive abilities, and emotional inclinations [34] and [35]. Dewey (1966) defined critical thinking as the active and meticulous analysis of preexisting information and beliefs. CTS is therefore necessary to survive in the twenty-first century. CTS plays a vital role in student success [39], [40], and is a significant part of contemporary education [37], [38]. When used properly, this crucial ability aids students in making the right choices and solving problems efficiently [42, 43].

In this study, the CTS indicators were adapted from [30], namely: interpretation, analysis, inference and evaluation. Table 2 explains each CTS indicator [30].

Table 2.
CTS indicator.

No.	Indicator	Description
1.	Interpretation	➢ Interpretation involves categorizing, decoding, or explaining meaning. ➢ Interpretation involves understanding and communicating the meaning or intent of numerous events, circumstances, data, occurrences, decisions, agreements, beliefs, rules, procedures, and standards.
2.	Analysis	➢ Analyze ideas and dissect arguments. ➢ Determine true interpretations and conclusions from statements, questions, concepts, and explanations based on beliefs, decisions, experiences, reasons, information, or views.
3.	Inference	➢ Inference can be referred to as evidence, guess, or alternative. ➢ It involves identifying and selecting the necessary elements for a discussion by reducing data, declarations, principles, evidence, and judgment results while considering related information. Opinions, explanations, assertions, beliefs, and other presentations.
4.	Evaluation	➢ Evaluation is the process of assessing a statement or argument. ➢ It encompasses the analyzing a person's perceptions, experiences, situations, beliefs, and decisions, as well as assessing the reliability of a statement or presentation based on expected or actual inferential relationship between statements, questions, explanations, or other forms of presentation.

3. Methodology

3.1. Research design

In this study, the experimental study proposed by [44], [57] was used. The group received a pre-test and post-test which followed the sequence O1 X O2. The fluid pre-test (O1) assesses students' initial CTS before they receive treatment, which is conducted with the MOODLE-based MMSB (O2) learning model. Table 3 shows that several MOODLE features are incorporated into learning activities. Before using the research tools, three relevant experts were involved in verifying the learning tools, ultimately demonstrating that the content was valid and reliabel (Table 3).

Table 3.
Validity and reliability test of the instructional tools.

Instructional tools on MOODLE	**Lesson plan**	**Lecture even unit**	**Student worksheet**	**Student teaching material**	**Critical thinking skill test**	**Student response questionnaire**
Validity Score	4.00	4.00	3.95	4.00	4.00	4.00
Category	very valid	very valid	very valid	very valid	very valid	very valid
Reliability Score (%)	100	100	98	100	100	100
Category	excellent	excellent	excellent	excellent	excellent	excellent

Following that, a post-exam (O2) was given to evaluate the students' critical thinking. Three neutral observers took notes while observing the MOODLE-based MMSB model in use. Since the exam, students have been invited to investigate the learning process using the MMSB model based on MOODLE.

3.2. Sampling and Setting

The researchers gathered information from groups placed in specific areas. The MOODLE-based MMSB model was evaluated using cluster sampling at three Indonesian universities. There are 3 (three) clusters of universities, Cluster I (accreditation C), Cluster II (accreditation B) and Cluster III (accreditation A). This sample ensured high external validity [45] by selecting two classes per university with a total student population of 127 (see Table 4). The objective was to assess students' development of CTS while studying a basic physics of fluids course at each university.

Table 4.
Sample distribution per university.

University	**Cluster I**		**Cluster II**		**Cluster III**	
Study Program	Science education	Science education	Biology education	Mathematics education	Science education	Science education
Class	A	B	A	B	A	B
Number of sample (student)	25	22	18	21	20	21
Total sample (student)	127					

3.3. Learning Intervention

This MODLE MMSB approach offers interactive and mixed educational experiences through the use of structured educational resources (see Table 1). Researchers created and investigated these materials to meet the lesson's objectives, encourage student participation, and assess the liquid course's learning outcomes using the MOODLE platform.

3.4. Analysis Procedures

To assess the practicality of MOODLE-based MMSB, researchers reviewed observation sheets from three observers who meticulously recorded the deployment process. Each observer offered a rating scale with options for very good (4), good (3), barely acceptable (2), and poor (1). Next, estimations are presented to determine the model's practicality. The researchers classified the model's applicability into four categories: "very good" ($3.50 \leq P \leq 4.00$), "good" ($2.50 \leq P \leq 3.50$), "fairly good" ($1.50 \leq P \leq 2.50$), and "not good" ($1.00 \leq P \leq 1.50$). Based on the category, the MOODLE-based MMSB model is judged practicable if it obtains a score of 2.5 or higher. The researcher then reviewed the students' questionnaire replies and critical thinking assessments. The CTS test consists of twelve questions that focus on one of the four CTS metrics: analysis, interpretation, inference, or evaluation. The researcher then analyzed the data, including standard t with paired samples and N gain analysis (see Formula 1). They did this with SPSS version 28. Next, the results were categorized according to certain criteria (see Table 5).

$$\text{N} - \text{Gain} = \frac{S_{post} - S_{pre}}{S_{max} - S_{pre}} \qquad (1)$$

Information: N-Gain = normalized gain value; Spost = post-test score; Spre = pre-test score; Smax = maximum CTS value.

Table 5.
N-Gain criteria.

N-Gain	**Criteria**
0.70 < N-Gain	High
0.30 ≤ N-Gain < 0.70	Medium
N-Gain < 0.30	Low

The employed used the Shapiro-Wilk test to evaluate whether their data exhibited normality. They ran further analyses on the data, including paired t tests, Wilcoxon tests, and Levene tests. They also manage data that does not fit normalcy standards. They also used an independent t-test to determine the consistency of average gains by comparing N-Gain scores between the two courses. The p-value is the most important decision point; if it is less than 0.05, the null hypothesis (H0) is rejected. This shows that there are considerable variances between the groups.

Next, descriptive statistics are employed to examine student responses to learning activities [47]. To calculate the percentage of positive responses, a value of one was assigned to a "yes" answer and zero to a "no" answer, and the percentage score was calculated using equation (2).

$$P = \frac{\sum K}{\sum N} x\, 100\% \qquad (2)$$

Information: P = percentage of response points; K = sum of those who answered “Yes”; N = sum of those who completed the questionnaire

The parameters for response scores are adopted in the evaluation design [44], which is ineffective if the N-Gain is between 0% and 20%; less effective if N-Gain 21% - 40%; fairly effective if N-Gain 41% - 60%, effective if N-Gain 61% - 80%, and very effective if N-Gain 81% - 100%. This learning model is deemed effective if the following conditions are fulfilled: (1) the CTS test results indicate a statistically significant improvement; (2) the average N-Gain score is categorized as “medium” category; (3) the average student response to the post course questionnaire show a satisfaction rate of 61% to 80% regarding the effective criteria.

4. Results

4.1. Results

The researchers found that the MOODLE-based MMSB model has been widely used in various student groups at universities. According to Figure 1, teachers apply six stages: orientation, organizing, exploration, mind mapping, creating and displaying work, and assessment. The results ranged between 3.50 and 4.00, which places it in the "very good" category, showing how practical this design is for assisting design learning activities.

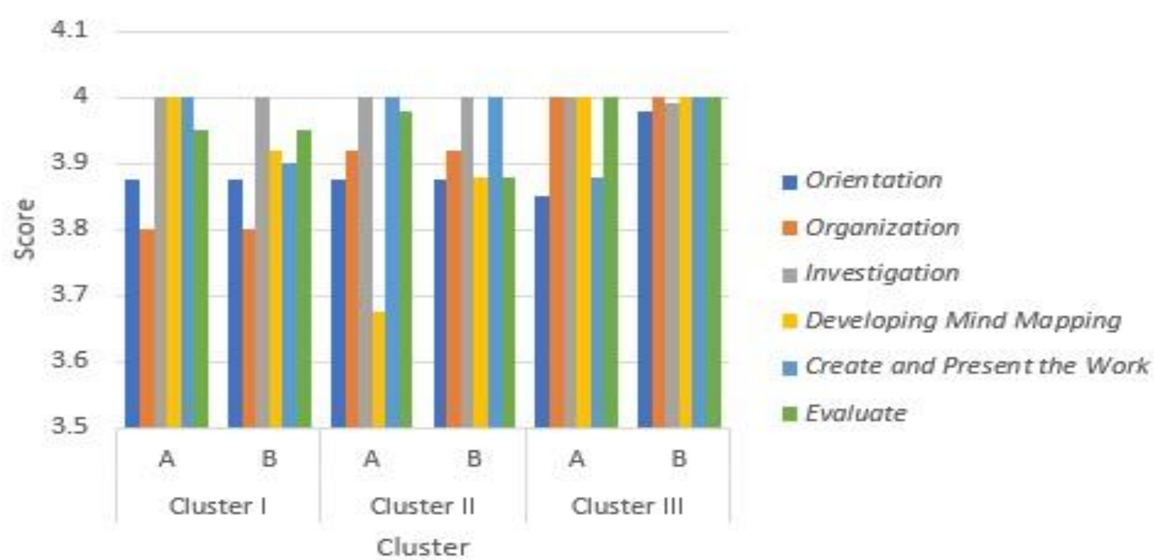


Figure 1.
The CTS implementation frequency.

The effectiveness of applying the MOODLE-based MMSB model is also assessed using CTS test results, normality and homogeneity tests, and student response questionnaires. Tables 6–9 illustrate how integrating MOODLE into the MMSB learning model significantly improves student CTS and offers valuable insights into its impact on pedagogy and student engagement. Table 7 displays the paired t-test results, revealing a significant difference in test scores before and after, with the p-value for Cluster I Class A and B being below 0.05. The Wilcoxon test's negative Z statistic further confirms that post-test scores are significantly higher than pre-test scores, indicating a statistical improvement at the 5% significance level. The average N-Gain score, which measures students' CTS improvement across various grades and institutions, was also further analyzed.

Table 6.
The normality test results.

University	Cluster I		Cluster II		Cluster III	
Class	A	B	A	B	A	B
Normality test (Shapiro-Wilk), $\propto = 0.05$						
Statistic	0.907	0.949	0.870	0.200	0.870	0.200
Df	19	20	17	20	24	21
Sig.	0.136	0.330	0.018	0.691	0.000	0.356
Normal distribution	Yes	Yes	No	Yes	No	Yes

Table 7.
The homogeneity test results.

University	Cluster I		Cluster II		Cluster III	
Class	A	B	A	B	A	B
Paired t-test, $\propto = 0.05$						
T	0.000	0.000	-	-	-	-
P	< 0.05	< 0.05	-	-	-	-
Conclusion	H_0 was rejected	H_0 was rejected	-	-	-	-
Wilcoxon t-test, $\propto = 0.05$						
Z	-	-	-3.726	-4.017	-4.373	-4.109
P	-	-	< 0.05	< 0.05	< 0.05	< 0.05
Conclusion	-	-	H_0 was rejected	H_0 was rejected	H_0 was rejected	H_0 was rejected
Levene's test, $\propto = 0.05$						
Sig.	0.808		0.732		0.020	
Homogene	Yes		Yes		Yes	

In this study, there are 4 (four) indicators of CTS that are measured. The values for each CTS indicator is shown in the Table 8.

ISSN: 2576-8484
Vol. 8, No. 6: 8682-8695, 2024
DOI: 10.55214/25768484.v8i6.3856

Table 8.
The mean values for each CTS indicator.

University	Cluster I		Cluster II		Cluster III	
Class	A	B	A	B	A	B
Mark	N-Gain	N-Gain	N-Gain	N-Gain	N-Gain	N-Gain
CTS indicator						
Analysis	0.66	0.55	0.51	0.54	0.61	0.45
Interpretation	0.55	0.61	0.49	0.70	0.38	0.55
Inference	0.76	0.74	0.62	0.53	0.80	0.77
Evaluation	0.39	0.43	0.27	0.44	0.75	0.52
Average N-Gain	0.59	0.58	0.47	0.55	0.63	0.57
Criteria	Medium	Medium	Medium	Medium	Medium	Medium

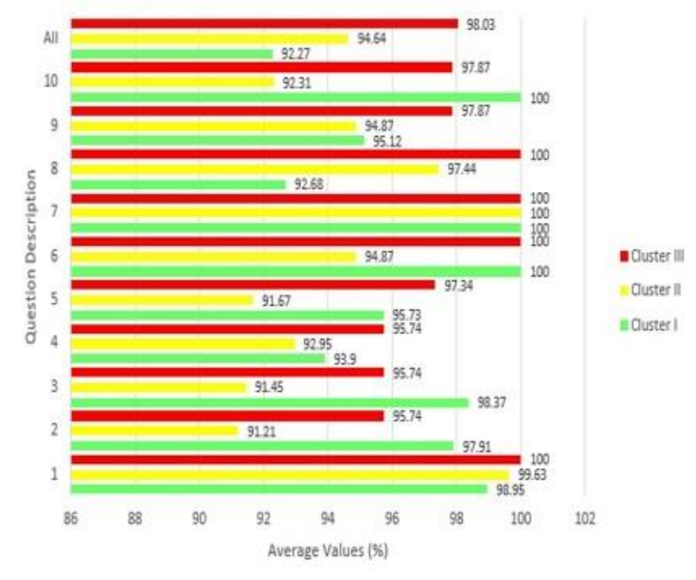
The data in Table 8 emphasizes the dominant performance advantage, and Cluster III's class A reaches the highest estimation of 0.63. As indicated by the data in the Table 8, the conclusion indicator indicates that the medium and important criteria have the most important medium estimation of all participating universities. Group III universities had the highest mean value of 0.80, while Group II universities had a lower mean value of 0.27 (evaluation index) for Class A, which were classified as poor performers.

The researchers examined the consistency of CTS average N-Gain values across all participating universities. Table 9 shows that the results are not different. Independent t tests and Wilcoxon tests yielded p values greater than 0.05. These findings led the researchers to accept the null hypothesis, which states that there is no statistical difference between the N gain values. These findings show that the CTS of students at participating universities increased regularly and considerably.

Table 9.
The results of the independent t-test and Wilcoxon test.

University	Cluster I	Cluster II	Cluster III
Independent t-test $\propto = 0.05$			
P	0.945	-	-
Conclusion	H_0 accepted (consistent)	-	-
Wilcoxon, $\propto = 0.05$			
P	-	0.135	0.075
Conclusion	-	consistent	consistent

The survey outcome also reveals that the majority of students favored the use of the MOODLE-based MMSB model in learning. This model has proven to be a successful teaching tool, particularly for physical learning, as illustrated in Figure 2. In addition, the average student response rate is much higher than 80%.



Question description:

1	:	What do you think about the MOODLE-based MMSB model?
2	:	What is your opinion on the advanced components and activities features of the MOODLE-based MMSB model?
3	:	Can you comprehend the learning components through the MOODLE-based MMSB model?
4	:	What did you learn from the CTS activities (interpretation, analysis, inference, evaluation)?
5	:	Do you understand how to use the CTS components to interpretation, analyze, inference, and evaluate?
6	:	Do the learning activities become fascinating?
7	:	How is the lecturer's guidance during the implementation process?
8	:	Has your CTS improved with the MOODLE-based MMSB model?
9	:	Does the MOODLE-based MMSB model help you with the physics course?
10	:	What do you think of teaching the other subject or material using the MOODLE-based MMSB model?

Figure 2.
The results of student response questionnaires.

The findings of the questionnaire responses provided to students from Cluster 3 Universities are displayed in Figure 2. The average effectiveness of the Cluster I, Cluster II, and Cluster III surveys was 92.27%, 94.64%, and 98.03 percent, respectively. All things considered, students reported that the MOODLE-based MMSB model greatly enhanced their CTS.

4.2. Discussion

The results highlight that the MOODLE-based MMSB model has effectively improved CTS among students, especially in Basic Physics courses. When learning through the MOODLE-based MMSB model, students engage in lecture activities according to the phases established by the instructor. Instructors implement six phases of this model, which are orientation, organizing, investigating, developing mind mapping, creating and presenting assignments, and evaluating. The interactions between lecturers and students during the learning process using the MOODLE-based MMSB model are illustrated in Table 1. The information from Table 1 indicates that the MOODLE-based MMSB model supports blended learning and enables students to practice CTS. This is evidenced by the incorporation of CTS indicators developed throughout each phase of the MOODLE-based MMSB model. The CTS indicators addressed in this educational framework are interpretation, analysis, inference, and evaluation, adapted from the CTS indicators in [30], which are detailed in Table 2.

The practicality of the MOODLE-based MMSB model is based on the feasibility evaluation of the learning model. Data related to the effectiveness of each phase of the model, organized into three clusters, is presented in Figure 1. Overall, the MOODLE-based MMSB model is practical, as observation data from model implementation at each phase falls into the very good category. Effective teaching instruments and materials contribute to the development of a successful learning model. It is crucial for teaching materials to be well-crafted since they serve as learning plans for educators, resources for learning, and evaluation tools post-instruction [48], [49]. Figure 1 illustrates how integrating mind mapping, blended learning, and LMS MOODLE satisfies the practical needs of other effective learning models [49], [50], and [51]. A model is said to be of high quality when it meets the criteria of validity, practicality, and effectiveness [58]. As a result, students' CTS in physical education is successfully promoted. The environment, both physical and socio-cultural, can make a specific contribution to students' learning experiences [59]. The availability of supporting tools to run a valid and reliable model is one of the aspects that affects the MOODLE-based MMSB model's viability and success, as indicated in Table 3.

The effectiveness of the MOODLE-based MMSB learning model is evidenced by: (1) a statistically significant improvement in CTS test scores; (2) an average N-Gain classified at least in the medium category; (3) consistent N-Gain across groups; and (4) an average student response to the post-learning questionnaire, indicating a satisfaction level of 61% to 80% within practical criteria. Research data must first undergo homogeneity and normality testing before undergoing statistical analysis. The results of Tables 6 and 7 demonstrate that the cluster I data has a normal and homogenous distribution, allowing for the employment of parametric statistical tests. However, data from classes II and III must still match conventional criteria, therefore nonparametric statistical tests are applied. Each CTS indicator for group I, II, and III is medium categorized as medium according to the average N-Gain analysis. For independent t-test results for group I, II, and III exceeded the 5% significance level, with respective values of 0.945, 0.135, and 0.075. These findings imply that the average N-Gain shows no significant differences (consistency) between the two classes in each respective cluster. To further substantiate the effectiveness of the MOODLE-based MMSB model, student feedback on the model was gathered, as displayed in Figure 2.

Generally, students expressed that the MOODLE-based MMSB model employed in their learning proved highly effective for cultivating CTS. The evidence leads to the conclusion that the MOODLE-based MMSB model effectively trains CTS, as reflected by the average N-Gain score falling within the medium category, the consistency of the N-Gain values across both classes in each cluster, and positive student feedback regarding the model's use in education. The analysis of data for each CTS indicator reveals that the inference indicator demonstrates the highest N-Gain value. Utilizing mind mapping aids students in recognizing and deducing complex formulas during their investigation process. Initially, students encountered challenges with CTS, which aligns with studies indicating that e-learning methods for cultivating CTS require prolonged intervention and ongoing practice.

Similarly, it has been noted that repetitive practice of CTS is essential for enhancing procedural knowledge significantly. The value attributed to the MOODLE-based MMSB model stems from its user-friendliness and effective material delivery, aiding students in better grasping physics concepts. This perspective is supported by research that indicates a well-structured learning model can enhance students' CTS across different formats. Table 9 indicates a positive educational experience that arises from merging mind mapping science (MMSB) with MOODLE. This model fulfills numerous criteria aimed at boosting students' CTS while making the learning experience more accessible and enjoyable. Consequently, the MOODLE-based MMSB model emerges as a promising framework for future development within educational settings. The findings reinforce the notion that the MOODLE-based MMSB model represents an innovative learning strategy that educators can implement to cultivate students' CTS.

5. Conclusion

According to the research findings conducted at 3 (three) different university clusters revealed that the frequency of model performance data ranged from 3.50 to 4.00, with some falling into the very good category, demonstrating that the learning model is being applied realistically to enhance CTS. In addition, the MOODLE-based MMSB learning model is effective in enhancing students' CTS, as demonstrated by: (1) the average N-gain score in both classes in 3 (three) university clusters is in the medium category ($0.30 \leq$ N-Gain < 0.70); (2) average N-Gain shows no significant differences (consistency) between the two classes in each respective cluster; (3) the student response questionnaire results indicated that more than 80% of students deemed this model to be highly effective in practicing CTS. These results validate that the integration of MOODLE with the Mind Mapping Science Blended learning model can improve CTS when applied consistently within a structured educational framework. Future research should strive to include broader demographics, including participants from diverse backgrounds, to increase the applicability of these findings. This research has just been carried out and tested in Basic Physics courses, additional research is required to adapt the phases of the MOODLE-based MMSB model to subject beyond basic physics.

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