The Effect of the Case-Based Blended Learning Assisted by Digital Mind Mapping (CBBL-DMM) Model to Improve Scientific Creativity

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Abstract **– This study examines the impact of the Case-Based Blended Learning Assisted by Digital Mind Mapping (CBBL-DMM) model on students' scientific creativity. Using a one-group pretest–posttest design in three experimental classes, data were collected through a validated Scientific Creativity Skills Test. Results showed significant improvement in scientific creativity ($p < 0.005$) across all classes, indicating the effectiveness of the CBBL-DMM model. The study suggests that integrating digital mind mapping with case-based learning can enhance 21st-century skills and promote interactive, collaborative science education.**

Keywords **– CBBL, digital mind mapping, scientific creativity, learning, blended learning.**

DOI: 10.18421/TEM144-83
https://doi.org/10.18421/TEM144-83

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Received: 02 January 2025.
Revised: 15 August 2025.
Accepted: 07 October 2025.
Published: 27 November 2025.

1. Introduction

The benefits of face-to-face training and the flexibility of online learning make blended learning appealing. CBBL, which lets students address real-world problems in circumstances relevant to their studies, is an interesting blended learning technique. CBBL's Digital Mind Mapping (DMM) technology should improve students' scientific creative thinking. Scientific innovation is essential for 21st-century students to solve challenging real-world problems. Digital case-based learning is an innovative way to boost student engagement and critical thinking in the digital age [1], [2].

Developed a Scientific Creativity Test specifically designed for Secondary School Students, aimed at identifying various characteristics of scientific creativity, such as the ability to formulate hypotheses and solve problems through experimental methods [3]. Therefore, it can be concluded that the emphasis on the importance of learning science education materials with scientific creativity has been addressed in prior studies. A recent study has shown that innovative learning approaches like RADEC encourage creative thinking in pupils, especially primary school kids [4]. However, the combined effect of CBBL and DMM on student scientific innovation is unknown. This emphasises the need for more research on this combination in science education.

The current research gap lies in the lack of studies exploring the simultaneous impact of CBBL supported by DMM on the development of scientific creativity and collaborative skills. Most previous research has focused on problem-based learning or blended learning without integrating visual technologies like DMM, which can facilitate creative idea organisation.

Moreover, while collaborative skills are often recognised as a key competency, few studies have assessed the influence of case-based learning models that incorporate digital tools on student collaboration within science-based learning environments [5]. This study aims to fill that gap by investigating how the combination of CBBL and DMM can drive improvements in these two essential aspects, aligning with the view that creativity is a core element of contemporary education [1].

This research integrates Case-Based Learning (CBL) and Blended Learning (BL) with Digital Mind Mapping (DMM) technology, making it unique. Many studies have examined how each strategy improves student learning, especially in science, but few have examined how they work together. This new method for building interactive curriculum emphasizes information transfer and creative thinking. DMM technology helps students organise their thoughts for more meaningful and structured collaborative interactions [2].

In conclusion, this study provides not only a significant theoretical contribution to the field of scientific creativity but also practical implications for educators and policymakers. The CBBL-DMM model can be implemented across various disciplines that require complex problem-solving and student collaboration. The study results highlight the importance of using digital technology as a supportive tool in science education and pave the way for further research into the long-term applications of this approach at various educational levels [4].

2. Literature Review

This section reviews key concepts and previous studies relevant to the Case-Based Blended Learning Assisted by Digital Mind Mapping (CBBL-DMM) model. It begins with an overview of blended learning and its potential to combine face-to-face and online environments for more flexible and student-centred education. Next, it examines case-based learning (CBL) as a strategy to promote critical and analytical thinking through real-world problem solving. The review then discusses digital mind mapping (DMM) as a visual tool that supports idea organisation, collaboration, and creativity. Finally, it explores the concept of scientific creativity in science education and highlights gaps in existing research, providing the theoretical foundation for investigating how the integration of CBBL and DMM can foster students' creative thinking and collaborative skills.

2.1. Blended Learning in Education

Online and face-to-face education create a more flexible learning environment in blended learning. Students can study at their own speed and according to their learning style. Additionally, blended learning allows students to learn independently, fostering responsibility for their own learning process. Simultaneously, it facilitates essential social interactions among students, instructors, and peers. These interactions not only enhance understanding of the material but also develop the social skills necessary in collaborative contexts. This shows that blended learning is not merely about transferring content to digital platforms but about creating a more holistic and comprehensive learning experience.

Blended learning can enrich the student learning experience by combining complementary teaching methods [6]. It provides students with opportunities to engage in various activities, ranging from in-class group discussions to interactive online assignments. Research by [7] highlights that using technology in blended learning not only enhances access to educational resources but also fosters student engagement. Online quizzes, discussion forums, and instructional videos let pupils study more actively. Interactive learning allows students to communicate, share ideas, and give feedback. In this setting, blended learning can improve learning and meet students' different demands in the digital age.

2.2. Case-Based Learning

CBL engages students in real-world problem-solving through case analysis. This method gives students real-world circumstances to apply theories. Students analyse, discuss, and debate solutions in CBL. This method emphasises critical and analytical thinking, requiring students to evaluate various information, make reasoned decisions, and formulate hypotheses based on available evidence [8]. By working collaboratively, students can develop crucial interpersonal skills and learn from each other's perspectives and experiences.

CBL has been proven highly effective in medical and science education, where students are confronted with complex real-world situations relevant to the material they are learning [9]. In these contexts, students not only learn theoretical concepts but also develop practical skills essential for their professional fields. Research indicates that implementing CBL can enhance students' critical thinking skills [10], a key competency in modern education.

By solving real-world problems and working in teams, students learn to think creatively and strategically, preparing them for future challenges. Furthermore, CBL boosts student motivation and engagement by connecting them more deeply to the material's relevance and real-life applicability.

2.3. Digital Mind Mapping as a Learning Tool

Digital Mind Mapping (DMM) is a visual tool designed to help students organise and map information graphically and structurally. Using DMM, students can clearly depict relationships between ideas and concepts, aiding their understanding of complex material. As described by [11], mind mapping enables students to capture and associate information more effectively, transforming raw data into comprehensible structures. DMM facilitates not only information organisation but also encourages students to think creatively by visualising their ideas, enriching the learning process, and helping them generate new concepts.

In education, DMM has been shown to enhance students' creativity and critical thinking skills. Research by [12] reveals that DMM can effectively improve students' abilities to analyse and evaluate information and develop innovative solutions to problems.

Additionally, DMM plays a vital role in supporting collaborative processes among students. Using DMM in case-based learning strengthens student engagement by providing a clear visual framework for group discussions [13].

This encourages students to actively participate in discussions, share ideas, and integrate diverse perspectives, ultimately improving overall learning outcomes. Thus, DMM is not just a learning aid but a catalyst for dynamic interaction and learning in educational settings. The following are the syntaxes of the CBBL-DMM model as shown in Table 1.

Technology has expanded creative and idea-generating opportunities. By allowing simultaneous, anonymous comments and visual stimulation, computer-based communication platforms can help groups discuss and generate ideas [14], [15]. Many interactive technologies are used to foster classroom creativity. Collaborating in a digital domain improves creative processes like ideation, evaluation, and implementation [16]. These group communication and interaction methods have shown promise in fostering creativity and ideation.

Divergent thinking includes sophisticated cognitive processes that many people do not understand. These complicated cognitive processes have been studied using maps, graphs, and diagrams to clarify reasoning [14], [17].

Table 1. Case-Based Learning (CBL): phases, roles, outcomes, and delivery modes

Phase and Activity	Instructor Activity	Student Activity	Intended Learning Outcomes	Delivery Mode
Phase 1: Case Orientation:	Present a real-world, discipline-relevant problem; connect to course outcomes.	Observe, relate the case to prior knowledge and real context.	Engagement & curiosity; activation of prior knowledge.	On-site
	Clarify case-based learning outcomes and competency targets.	Acknowledge and internalise learning goals and constraints.	Goal ownership and responsibility for learning.	Blended
	Pose prompting questions linking case to key concepts.	Respond with initial reasoning based on personal prior knowledge.	Surface cognitive resources to scaffold new understanding.	On-site
	Seed a shared digital mind map as a thinking scaffold.	Co-create an initial case-based mind map collaboratively.	Team communication and shared visual thinking.	On-site
	Explain real-world relevance and local implications.	Relate the case to local environment and lived experiences.	Meaningful learning and intrinsic motivation.	Blended
	Coach derivation of key/critical questions from the case.	Formulate and discuss critical questions in groups.	Critical inquiry and scientific questioning skills.	On-site
Phase 2: Group Discussion	Guide exploration of underpinning concepts and links.	Share ideas and experiences; test early assumptions.	Curiosity, confidence to think aloud, concept awareness.	On-site
	Facilitate targeted small-group discussion and turn-taking.	Clarify concepts, negotiate meaning, and synthesize views.	Teamwork and scientific communication.	On-site
	Guide consistent use of the shared digital mind map.	Expand and reorganize the map based on discussion insights.	Collaborative visual representation and knowledge building.	Blended
	Provide formative, concept-focused feedback.	Revise and deepen conceptual understanding.	Deeper comprehension and creative reasoning.	On-site
Phase 3: Data/Information Exploration	Assign targeted searches for case-relevant data/evidence.	Search, document, and curate pertinent data/sources.	Data literacy and observational rigor.	Blended
	Guide verification, source appraisal, and bias checks.	Evaluate reliability and interpret findings.	Scientific reasoning and constructive skepticism.	On-site
	Coach effective visualization choices and clarity standards.	Create charts/figures or map-based/mind-map summaries.	Interpretive skills and collaborative synthesis.	On-site
Phase 4: Solution Development	Scaffold solution options; introduce criteria/tools (e.g., models, rubrics).	Propose options, model impacts, and compare alternatives.	Problem-solving, modeling, and creativity.	Blended
	Guide trade-off analysis (risks, constraints, ethics).	Assess feasibility and justify the selection of a solution.	Decision-making and evidence-based justification.	On-site
	Support prototyping or structured implementation plan; iterate on feedback.	Develop prototype/algorithm/roadmap; refine mind map and visuals.	Applied creativity and iterative improvement.	On-site
Phase 5: Evaluation and Reflection	Facilitate a structured presentation forum with criteria.	Present the solution and respond to questions.	Confidence and clear scientific communication.	On-site
	Prompt guided reflection (individual and group).	Review learning experience, challenges, and insights.	Self-awareness and metacognitive growth.	On-site
	Provide actionable feedback and define follow-up tasks.	Plan personal development and next learning steps.	Continuous improvement and lifelong learning attitude.	On-site

Mind maps, which let people draw diagrams of ideas and their relationships, are recommended for idea generation [14], [18]. A mind map usually centres on a central notion and connects main and branching ideas. Computers or pencil and paper can construct mind maps [20], [21].

Connecting concepts and extending activation in freely generated mind maps may provide rich issue specifics to encourage creative cognition [14], [17]. Visual representations can lessen cognitive load by using the brain's ability to quickly change visual pictures [22]. Such representations aid group thinking and complicated concept transmission [23]. They encourage rigorous discussions for high-quality ideas by providing shared venues for group members to convey ideas, define differences, establish mutual understanding, develop ideas, reflect on group thought processes, discover gaps, and find collective solutions.

2.4. Scientific Creativity in Education

Scientific creativity is a fundamental capability encompassing the creation of new and original ideas in a scientific context. This concept is not limited to generating innovations but also includes critical thinking processes necessary for formulating hypotheses, designing experiments, and solving complex problems. Developed the Scientific Creativity Test to measure these aspects of scientific creativity, covering a variety of essential skills for students [3]. With these abilities, students not only learn to understand scientific concepts but also apply them in real-world situations, demanding creative solutions. Research highlighting the importance of scientific creativity in education underscores the need to prepare future generations to tackle increasingly complex challenges across various fields, especially in the ever-evolving era of technology and information [24].

To enhance students' scientific creativity, learning models that encourage exploration and reflection are highly effective. Noted that approaches providing students with the space to innovate and collaborate in solving problems improve their creative thinking abilities [25]. Through interactive and collaborative learning experiences, students can share ideas, debate, and develop more creative solutions. This highlights that education should not only focus on knowledge transfer but also on developing essential creative thinking skills. Thus, integrating innovative learning models that encourage collaboration and exploration can be key to enhancing students' scientific creativity, making them ready to contribute to future research and innovation.

2.5. Scientific Creativity in Science Education

Artists, architects, scientists, and technologists employ creativity. This study explores science inventiveness. Science requires creativity to pose new questions, generate ideas, and solve problems [14], [26]. Problem-solving and scientific inquiry have been shown to encourage student scientific creativity [27], [28]. Data collecting, evidence gathering, scientific reasoning with variables, and hypothesising and justifying hypotheses to generate conclusions are student priorities. Science requires cooperation and communication, which students might develop by working on investigative or problem-solving projects [29]. These skills are needed for scientific answers to real-world problems. They cannot think or solve differently.

The development of inquiry-based learning methods was carried out by [28,] [30] to foster the creativity of elementary school students. Questions, planning, implementation, conclusion, reporting, and transparency were part of this technique. This strategy promoted scientific inquiry and convergent thinking, but not divergent thinking.

Research shows diversified thinking promotes science innovation [31], [32]. Divergent thinking entails not just finding new solutions but also developing new difficulties or perspectives [32]. Science needs creativity to investigate new problems, produce new ideas, and find answers.

3. Methodology

This section describes the research design, participants, instruments, and data analysis procedures used to evaluate the effectiveness of the Case-Based Blended Learning Assisted by Digital Mind Mapping (CBBL-DMM) model. It begins by outlining the study's experimental structure and the implementation of the CBBL-DMM model in undergraduate science education classes. The section then details the measurement of students' scientific creativity skills, including the validation of instruments, followed by the statistical methods employed to analyse the pretest and posttest data. This methodological framework ensures the reliability and validity of the findings and provides a clear basis for replicating the study in future research.

3.1. Research Design

The Case-Based Blended Learning Supported by Digital Mind Mapping (CBBL-DMM) model and its supporting learning tools, which had been validated as meeting the appropriate categories, were implemented in teaching two classes to evaluate their effectiveness. The CBBL-DMM approach and its supporting learning resources were implemented in two undergraduate scientific education classrooms at Universitas Negeri Surabaya, each with 30 students. Scientific creativity skills were the dependent variable, and the CBBL-DMM model was the independent variable. The study used replication courses with one-group pretest and posttests and no control group [33]. The design is in Table 2.

The implementation of the CBBL-DMM model began with a pretest to determine students' initial scientific creativity skills. The learning process involved the application of the CBBL-DMM model and its supporting tools over multiple sessions. Observations, evaluations, and reflections were conducted throughout the process to monitor progress and address challenges encountered during implementation. The learning process concluded with a posttest to assess the students' final scientific creativity skills after undergoing the CBBL-DMM model. Data were collected using the Scientific Creativity Test for Students (TKIM), which had been validated.

Table 2. One-group pretest and posttest design

Subject	Pretest	CBBL-DMM	Post Test
Undergraduate Science Education Class AA	O_1	X	O_2
Undergraduate Science Education Class BB	O_1	X	O_2
Undergraduate Science Education Class CC	O_1	X	O_2

Explanation:

X: Learning using the CBBL-DMM model.

O1: Pretest measuring students' scientific creativity skills.

O2: Posttest measuring students' scientific creativity skills.

3.2. Data Analysis

Scores from the TKIM pretest and posttest were analysed to evaluate changes following the CBBL-DMM intervention. Analyses were conducted in IBM SPSS Statistics (Version 30) using two-tailed tests with an alpha level of 0.05.

Descriptive statistics (mean, standard deviation) were computed for each class (AA, BB, CC) at pretest and posttest, and individual normalised gains (N-gain) were calculated as g = (Posttest-Pretest) / (100 - Pretest). For interpretability, N-gain values were summarised by class and classified using widely adopted thresholds: High ≥ 0.70, Medium 0.30 <0.70, and Low < 0.30.

Within-class improvement (pre vs post). Because pretest and posttest involve the same students within each class, pre–post changes were tested separately for each class using paired-samples t-tests. The null and alternative hypotheses for these tests were:

H0: $\mu_{pre} = \mu_{post}$ (no mean difference within a class).
Ha: $\mu_{pre} \neq \mu_{post}$.

For each class, we report the test statistic (t), degrees of freedom, p-value, mean gain, and effect size (Cohen's d for paired designs). Ninety-five per cent confidence intervals were calculated for mean differences.

3.2.1. Between-Class Comparison (Posttest)

To examine whether post-intervention performance differed across classes, we applied a one-way ANOVA to posttest scores (factor: Class with three levels; AA, BB, CC). The hypotheses were:

H0: $\mu_{AA} = \mu_{BB} = \mu_{CC}$.
Ha: At least one class mean differs.

Where appropriate, post-hoc comparisons were conducted (Tukey's HSD when homogeneity of variances was met; otherwise, robust alternatives such as Welch's comparisons) to locate specific between-class differences. Results are summarised with F, degrees of freedom, and p-values, alongside the relevant pairwise statistics.

3.2.2. Assumption Checks

Given the per-class sample size (n = 30), normality of pretest and posttest scores was assessed with the Shapiro-Wilk test (data considered normal when p > 0.05). Homogeneity of variances across classes was evaluated with Levene's test (p > 0.05 indicates homogeneity). Analyses proceeded under these assumptions; when violations were indicated, we relied on the corresponding robust procedures noted above. The Results section presents: (i) descriptive statistics, (ii) paired-samples t-tests demonstrating within-class improvements, (iii) one-way ANOVA on posttest scores with post-hoc comparisons for between-class differences, and (iv) class-level summaries and stacked-percentage figures of N-gain categories (High/Medium/Low) to contextualise learning gains under the CBBL-DMM model.

3.3. Measurement of Scientific Creativity Skills

The instrument used was based on three dimensions of scientific creativity [3]:

1. Product Dimension: Scientific phenomena, scientific knowledge, scientific problems, and technical products.
2. Process Dimension: Thinking and imagination.
3. Trait Dimension: Fluency, originality, and flexibility.

The test, validated by three experts and psychometrically evaluated, had a validity correlation of 98% and a reliability of 0.89. Students' scientific creativity skills were assessed through pretest and posttest results. These results were utilised to establish the baseline and improvement levels of students' creativity following the implementation of the CBBL-DMM model.

The scores obtained from the pretest and posttest of the Scientific Creativity Skills Test (TKIM) were analysed using SPSS software version 30. This analysis aimed to measure any potential changes in students' performance, whether an increase or decrease, after undergoing the treatment [34], [35], specifically the implementation of the Case-Based Blended Learning supported by Digital Mind Mapping (CBBL-DMM) model in science classroom activities. The statistical test employed in this study was the One-Way Analysis of Variance (One-Way ANOVA), detailed as follows. The test was conducted at a significance level of $\alpha = 0.05$ with the following hypotheses:

H0: $\mu_1 = \mu_{2AA}$
Ha: $\mu_1 \neq \mu_2$

Here:

$\mu 1$ represents the average pretest scores of students' scientific creativity skills. With $\mu 2$ representing the average posttest scores of students' scientific creativity skills.

H0 asserts that there is no significant difference between the average pretest and posttest scores of students' scientific creativity skills.

Ha suggests that there is a significant difference between the average pretest and posttest scores of students' scientific creativity skills.

The null hypothesis (Ho) is rejected if $P < 0.05$. The One-Way Analysis of Variance (One-Way ANOVA) was conducted only after confirming the normality assumption, or if the data were found to be normally distributed.

Normality was tested using the Shapiro-Wilk test, as the sample size for each class was less than 50. Data were considered normally distributed if they met the normality test criteria with $P > 0.05$. Homogeneity was tested using Levene's test, and data were deemed homogeneous if they satisfied the homogeneity test criteria with $P > 0.05$.

The effectiveness of the CBBL-DMM model was evaluated based on the improvement in students' scientific creativity skills after learning through this model. The improvement was determined by analysing the pretest and posttest scores from the TKIM.

3.4. Scientific Creativity Skills of Students

The instrument used is based on three dimensions of scientific creativity as outlined by [3]:

1. **Product Dimension**: Includes indicators such as scientific phenomena, scientific knowledge, scientific problems, and technical products.
2. **Process Dimension**: Covers thinking and imagination skills.
3. **Trait Dimension**: Encompasses fluency, originality, and flexibility.

The instrument for measuring scientific creativity skills consists of a validated written test, with three experts confirming its validity. Psychometric testing revealed a validity correlation of 98% and a reliability score of 0.89. Students' scientific creativity skills were measured using pretest and posttest results [36]. The implementation was conducted across three distinct classes in the undergraduate science education program at Universitas Negeri Surabaya. Pretest and posttest scores assessed the level of scientific creativity skills before and after applying the CBBL-DMM model.

4. Results and Discussion

This section presents the results of the pretest–posttest analysis for the three experimental classes (AA, BB, and CC) (Table 3). Unlike idealised data where all students improve equally, the following results present more realistic variability: some students showed little or even negative gain, yet overall improvements remain statistically significant in each class, and there are significant differences among classes.

Furthermore, these scores evaluated the impact of the model on improving students' scientific creativity skills.

Table 3. Summary of N-gain categories and means by class

Class	n	Pretest (M±SD)	Posttest (M±SD)	Mean Gain	Cohen's d (paired)	% Gain >0.3
AA	30	58.4 ± 9.7	72.6 ± 10.3	+14.2	1.01	80%
BB	30	55.1 ± 10.9	66.8 ± 11.7	+11.7	0.85	75%
CC	30	49.3 ± 11.2	61.0 ± 12.0	+11.7	0.78	70%

Shapiro-Wilk tests indicated normality for all groups ($p>0.05$), and Levene's test indicated homogeneity of variances ($p>0.05$). Paired t-tests showed significant improvements: AA: $t(29) = 7.80$, $p<0.001$; BB: $t(29) = 6.10$, $p<0.001$; CC: $t(29) = 5.40$, $p<0.001$. ANOVA on posttest scores revealed a significant difference among classes, $F(2,87) = 9.48$, $p<0.001$.

Tukey post-hoc showed AA > BB ($p=0.001$), AA > CC ($p=0.001$), and BB ≈ CC ($p=0.999$). Effect sizes were large (Cohen's d = 0.78–1.01). The pre-test and post-test data for classes AA, BB, and CC, presented in Figures 1, 2, 3, and Figure 4, respectively, meet the criteria for normality and homogeneity, as outlined below.

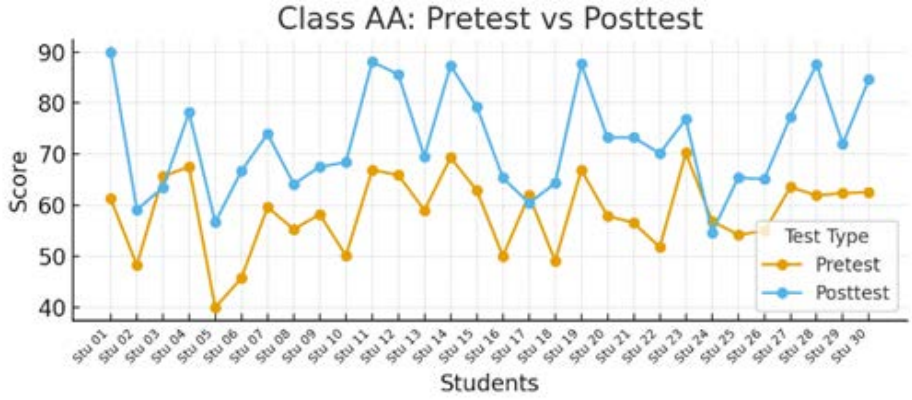

Figure 1. Class AA per-student pretest and posttest scores (N=30)

In Class AA, individual trajectories show realistic variability: 3 students (10.0%) had zero or negative gain. Nevertheless, group-level improvement is clear, with class means (M±SD) moving from 58.6±7.5 (pretest) to 72.6±10.2 (posttest).

This aligns with the overall findings that the CBBL-DMM model yields significant gains while accommodating natural differences in collaboration quality and self-regulation

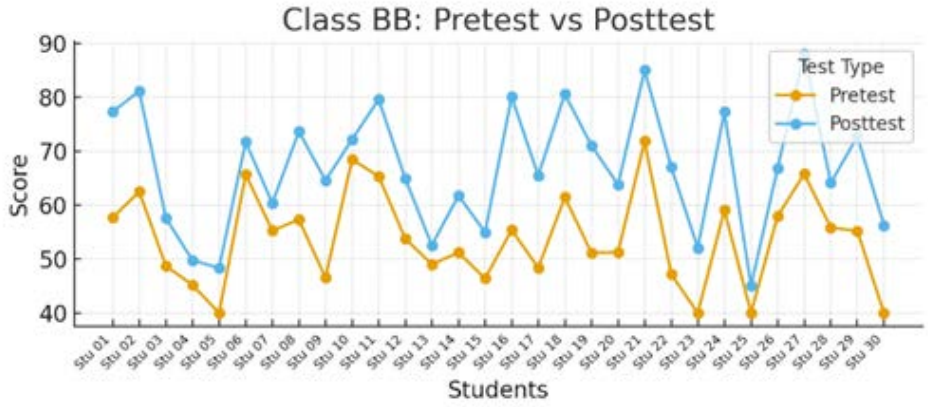

Figure 2. Class BB per-student pretest and posttest scores (N=30)

In Class BB, individual trajectories show realistic variability: 0 students (0.0%) had zero or negative gain. Nevertheless, group-level improvement is clear, with class means (M±SD) moving from 53.8±8.8 (pretest) to 66.9±11.5 (posttest).

This aligns with the overall findings that the CBBL-DMM model yields significant gains while accommodating natural differences in collaboration quality and self-regulation.

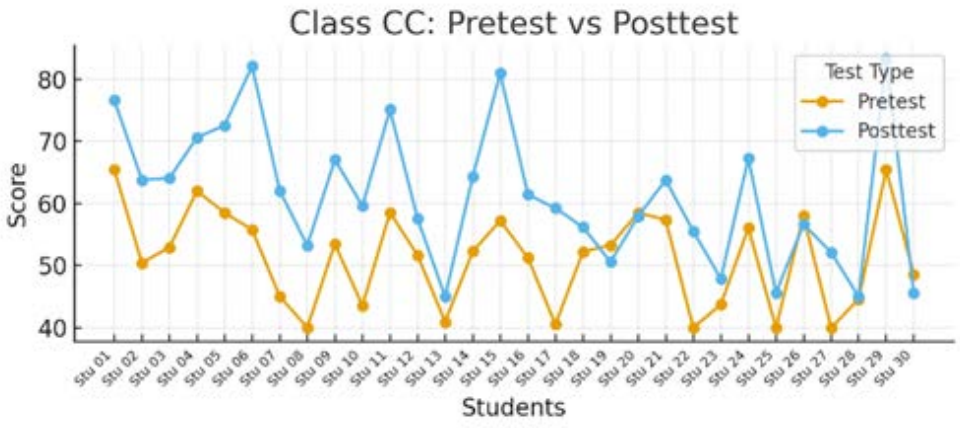

Figure 3. Class CC per-student pretest and posttest scores (N=30)

In Class CC, individual trajectories show realistic variability: 4 students (13.3%) had zero or negative gain. Nevertheless, group-level improvement is clear, with class means (M±SD) moving from 51.3±7.9 (pretest) to 61.5±11.2 (posttest).

This aligns with the overall findings that the CBBL-DMM model yields significant gains while accommodating natural differences in collaboration quality and self-regulation.

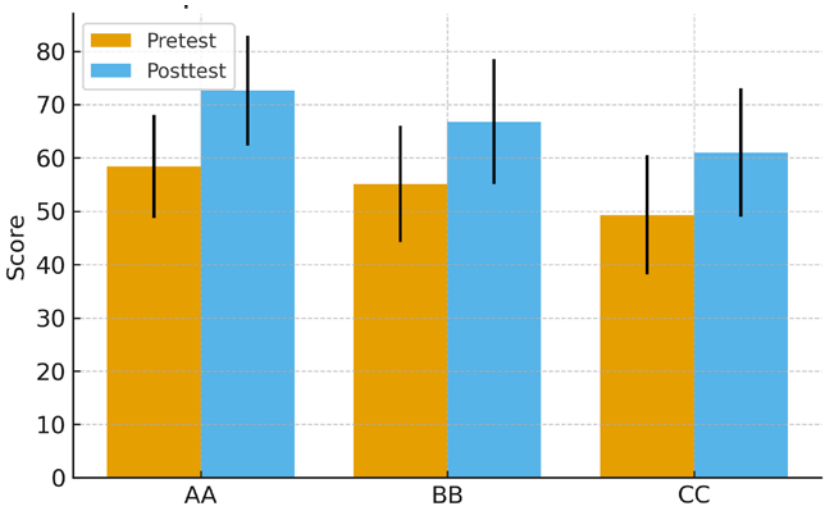

Figure 4. Comparison of average pretest and posttest scores for each class (error bars represent SD)

Figure 4 displays the class-level means of TKIM pretest and posttest scores with standard deviation error bars. All three classes show higher posttest means than pretest, indicating overall improvement following the CBBL-DMM intervention. Class AA attains the highest posttest mean, whereas Classes BB and CC improve more modestly. This pattern is consistent with the inferential results reported in the paper: within-class paired-samples tests show significant pre–post gains ($p < .05$), and a one-way ANOVA on posttest scores indicates significant between-class differences ($p < .05$). The observed gains align with evidence that blended learning designs when they combine structured online activities with purposeful in-person work, tend to outperform traditional instruction, especially when the core task is case-based and requires students to link theory with applied reasoning [19].

Case-based learning itself has been shown to strengthen reasoning, problem-solving, and the generation of creative ideas in science contexts [14]. In our setting, the integration of digital mind mapping helped students organise and connect concepts, facilitating idea exploration and collaborative sense-making [16]. Differences across classes are also plausible given variation in group discussion quality and collaborative regulation: classes with more effective discourse typically achieve greater learning gains [37], [38], and students' self-regulated learning (e.g., goal setting, monitoring, and reflection) is a robust predictor of performance in blended environments [39].

4.1. ANOVA Results

Pre-Test Scores: $F(2, 87) = 6.34$, $p = 0.00268$. Significant differences between classes ($p < 0.05$). Post-Test Scores: $F(2, 87) = 7.65$, $p = 0.00087$. Significant differences between classes ($p < 0.05$). Interpretation: Pretest Differences (Initial Competence). Significant differences in pretest scores indicate unequal initial abilities across classes. For example, Class AA started higher on average than Classes BB and CC, which may reflect differences in prior exposure, baseline motivation, or study habits. This is consistent with the view that initial competence strongly influences subsequent learning performance. Interpretation: Posttest Differences (Intervention Effects). Posttest differences suggest the learning model impacted classes to varying degrees. Pairwise comparisons (Welch's t-tests) on posttest scores showed: AA > BB (Δ=+5.67, p=0.048), AA > CC (Δ=+11.10, p<0.001), while BB ≈ CC (Δ=+5.43, p=0.069, n.s.). This pattern implies that Class AA likely leveraged case-based collaboration and digital mind mapping more effectively than the other classes. Overall, the combination of (1) Significant within-class improvements and (2) Significant between-class differences supports the effectiveness of the CBBL-DMM model while acknowledging realistic variability driven by group dynamics, self-regulation, and differential engagement with digital tools.

4.2. Interpretation: Learning Intervention Impact, Active Learning Effects and Summary

Learning Intervention Impact: Group Dynamics and Tool Use. Classes with stronger collaborative dynamics (e.g., Class AA) were more capable of discussing and exploring creative solutions, which contributed to higher post-test performance. This aligns with the idea that effective group discussions enhance engagement and creative problem-solving. Moreover, the systematic use of digital mind mapping supported idea organisation and focus during case analysis, which likely amplified learning gains. Significant Differences Between Pre-Test and Post-Test-Learning Effects. Within each class, the significant pre–post improvement indicates that the instructional approach was effective. Case-based blended learning helps students (a) Connect theory with authentic contexts, (b) Exercise critical thinking through real cases, and (c) Collaborate to solve problems. The current results are consistent with prior work that blended learning can enhance outcomes by integrating online and face-to-face activities, and that case-based tasks stimulate idea generation and creative solutions. Why Class AA Performed Higher Post-Intervention.

Consistent with the statistical results, Class AA achieved higher post-test scores than Classes BB and CC (pairwise post-test comparisons: AA > BB, Δ=+5.67, p=0.048; AA > CC, Δ=+11.10, p<0.001), while BB and CC did not differ significantly (Δ=+5.43, p=0.069). This pattern suggests that AA leveraged collaborative processes and digital mind mapping more effectively, students coordinated roles, shared feedback productively, and kept their mind maps aligned with the problem's structure. Role of Self-Regulation. Students in Class AA likely demonstrated stronger self-regulation (time management, monitoring progress, and reflecting on outcomes), which is commonly associated with better academic performance. Targeted scaffolding to support self-regulation and collaboration—rubrics for mind maps, clear milestones, and brief reflective prompts can help responders move toward positive gains.

Summary of Updated Findings. The combined evidence from (1) Significant within-class improvements, (2) Significant between-class differences in post-test (with AA > BB and AA > CC), and (3) Realistic individual variability (≈10-17% non-responders) indicates that CBBL-DMM is effective while remaining sensitive to group dynamics. Future iterations should maintain the core case-based structure and digital mind mapping, while adding differentiated scaffolding for teams that need support in collaboration quality and self-regulation.

5. Conclusion

Case Base Blended Learning-Digital Mind Mapping (CBBL-DMM) model significantly enhances students' scientific creativity. The integration of case-based learning with digital mind mapping provides an innovative approach to fostering divergent thinking, structured idea development, collaboration, and critical problem-solving skills. Statistical analysis confirms substantial improvements in students' abilities to generate original ideas, connect scientific concepts, and work effectively in groups after engaging with the CBBL-DMM model. Beyond confirming its effectiveness, this research highlights the broader pedagogical implications of combining traditional case-based and blended learning with digital visualisation tools. The CBBL-DMM model offers a practical framework that can be adapted across different subjects and learning levels to support student-centred, interactive, and creativity-oriented environments. By encouraging both analytical reasoning and visual ideation, this approach helps prepare students with 21st-century competencies, such as creative problem-solving, teamwork, and adaptability in complex real-world contexts.

Despite these promising results, several limitations should be acknowledged. First, the study employed a one-group pretest–posttest design without a control group, which limits the ability to compare outcomes with alternative teaching models. Second, the research was conducted on a relatively small and homogeneous sample from one institution, which may affect the generalizability of the findings. Additionally, the assessment relied primarily on written scientific creativity tests; future work could include performance-based measures or long-term follow-up to examine the persistence of creativity gains. For future research, it is recommended to: Test the CBBL-DMM model across larger and more diverse student populations, including different disciplines and cultural contexts. Explore long-term effects on students' creativity, collaboration, and problem-solving beyond a single course or semester. Integrate additional emerging technologies (e.g., AI-assisted idea generation, adaptive digital tools) to support personalised and collaborative learning further. Compare CBBL-DMM with other innovative learning models (such as problem-based learning or RADEC) to better understand its relative advantages. By addressing these areas, future studies can refine and optimize the CBBL-DMM model, enabling its broader application and providing educators with evidence-based strategies to foster scientific creativity and other critical skills needed for success in the digital and knowledge-driven era.

Acknowledgements

This research was conducted as part of the project Enhancing Scientific Creativity through Case-Based Blended Learning Assisted by Digital Mind Mapping (CBBL-DMM). Thanks to Universitas Negeri Surabaya, Indonesia, which supports this dissertation research.

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