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# The Effectiveness of COLLAPOSE: A Web-Based E-LKPD Incorporating Collaborative Problem Posing for Enhancing Elementary Students' Mathematical Creative Thinking

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## Abstract

Mathematical creative thinking is an important competency in elementary mathematics education; however, students often struggle to generate diverse, original mathematical ideas. This study examined the effectiveness of COLLAPOSE (Collaborative Problem Posing E-LKPD), a web-based electronic student worksheet that integrates collaborative problem posing with indicator-specific scaffolding to foster students' mathematical creative thinking. A quantitative approach employing a quasi-experimental, nonequivalent control-group design was adopted. The participants comprised 48 fifth-grade students from two intact classes at SDN Geluran 3, Sidoarjo, Indonesia. The classes were purposively selected based on characteristics identified in a preliminary study, particularly the heterogeneity of students' mathematical abilities as determined by the results of the Mathematics Ability Test (*Tes Kemampuan Matematika*/TKM). One class ( $n = 24$ ) was designated as the experimental group and received instruction using the web-based COLLAPOSE E-LKPD, whereas the other class ( $n = 24$ ) served as the control group and received conventional instruction using a non-web-based E-LKPD without collaborative problem-posing features. The intervention was implemented across six sessions, comprising a pretest, four 90-minute instructional sessions, and a posttest. Students' mathematical creative thinking was assessed through open-ended essay tasks designed to measure three dimensions: fluency, flexibility, and novelty. The assessment instrument demonstrated acceptable empirical item validity and good internal consistency, as indicated by a Cronbach's alpha coefficient of 0.862. Data were analyzed using N-Gain analysis and an independent-samples  $t$ -test, while Cohen's  $d$  was calculated to estimate the magnitude of the between-group effect. The experimental group achieved a mean N-Gain of 0.68, categorized as moderate, whereas the control group achieved a mean N-Gain of 0.21, categorized as low. Post-test performance was significantly higher in the experimental group ( $M = 82.33$ ) than in the control group ( $M = 67.46$ ),  $t(46) = 5.678$ ,  $p < .001$ . The findings provide initial empirical evidence that integrating collaborative problem posing, peer interaction, problem modification, and indicator-specific scaffolding within a web-based E-LKPD may support

the development of mathematical creative thinking among fifth-grade students within the context of the study.

**Keywords:** COLLAPSE; Collaborative Problem Posing; Elementary School; Mathematical Creative Thinking; Quasi-Experimental; Web-Based Learning.

## 1. Introduction

Creative thinking is a fundamental component of meaningful mathematics learning in elementary education, particularly as students are expected to move beyond routine procedures and engage in flexible, productive, and adaptive forms of mathematical thinking. Creativity has been widely recognized as an essential competence in contemporary education, as reflected in international frameworks and policy discussions emphasizing the development of learners' higher-order and future-oriented skills [1] [2]. In mathematics, creative thinking extends beyond obtaining correct answers; it encompasses the generation of multiple ideas, the consideration of mathematical situations from different perspectives, mathematical problem posing, and the exploration of alternative solution strategies [3] [4]. These processes position mathematics as a particularly important context for fostering flexible, divergent, and innovative forms of thinking among elementary school students [5] [6].

Elementary school represents a formative period for developing students' creative thinking, as children progressively develop more structured forms of reasoning while continuing to engage with concrete experiences. This developmental stage provides an important foundation for fostering mathematical creative thinking through learning experiences that connect abstract mathematical ideas with meaningful and accessible situations. Piaget's theory of cognitive development characterizes children aged approximately 7–11 years as being in the concrete operational stage, during which logical reasoning becomes increasingly developed when supported by concrete objects and familiar situations [7] [8]. This developmental characteristic is particularly relevant to elementary mathematics education, where students can engage with mathematical ideas through exploration, representation, and meaningful problem situations.

Given these developmental characteristics, mathematics instruction at the elementary level should provide opportunities for students to explore ideas, pose mathematical problems, and consider alternative solution strategies rather than relying exclusively on routine procedures [9] [10]. The importance of fostering creativity from an early age is also reflected in Indonesian educational policy. The Kurikulum Merdeka emphasizes the development of the Pancasila Student Profile, which identifies creativity as one of its dimensions. In elementary mathematics education, the curriculum further encourages students to develop higher-order mathematical competencies through activities that involve generating ideas, modifying information, and exploring alternative solution strategies [11]. Taken together, these developmental and policy perspectives provide a strong rationale for strengthening mathematical creative thinking through appropriately designed learning experiences at the elementary school level.

However, the need to strengthen creative thinking is also evident from international assessment data on Indonesian students. In PISA 2022, creative thinking was assessed for the first time among 15-year-old students across 64 countries and economies. Indonesia obtained a mean score of 19 out of 60 points, substantially below the OECD average of 33 points [12]. Only 5% of Indonesian students were classified as top performers, demonstrating proficiency at Levels 5 or 6, compared with 27% across OECD countries [12]. These findings indicate a substantial gap in creative thinking performance between Indonesian students and the OECD average. Although PISA assesses 15-year-old students rather than elementary school students, the results provide broader national evidence of the need to strengthen creative thinking throughout students' educational development [12].

The PISA 2022 findings provide further insight into the nature of this challenge. In Indonesia, only 31% of 15-year-old students attained at least the baseline proficiency level in creative thinking (Level 3), compared with 78% across OECD countries. At this level, students are expected to generate appropriate ideas for a range of tasks and begin to produce original ideas or solutions in familiar contexts. Moreover, Indonesian students performed relatively below expectations in creative thinking based on their mathematics and reading performance. Within the creative thinking assessment, Indonesian students showed relatively stronger performance in evaluating and improving ideas than in the other ideation processes, while the assessment overall highlighted challenges in generating diverse and creative ideas. PISA defines creative thinking as the capacity to generate, evaluate, and improve ideas to produce original and effective solutions. These findings reinforce the importance of providing learning experiences that deliberately engage students in idea generation, exploration, and refinement, particularly from the earlier stages of education [13].

Although the PISA findings concern 15-year-old students, they highlight the broader importance of examining how creative thinking can be fostered from the earlier stages of education. In the elementary school context, preliminary observations indicated that mathematics instruction was still frequently dominated by routine and procedure-based tasks, thereby providing limited opportunities for students to pose questions, modify problems, and explore alternative ideas [14]. A preliminary assessment further revealed an uneven profile of students' mathematical creative thinking across the indicators examined. Fluency was demonstrated at a moderate level, whereas flexibility and novelty were relatively low. As presented in Table 1, students were able to generate several relevant mathematical ideas but experienced greater difficulty in applying different strategies or perspectives and producing original mathematical ideas. This pattern suggests a need for learning experiences that provide sustained opportunities for students to generate, modify, and develop mathematical ideas through more flexible and diverse approaches.

**Table 1.** Preliminary Profile of Students' Creative Thinking Abilities

| Creative Thinking Indicator | Score | Category | Interpretation                                                                                                           |
|-----------------------------|-------|----------|--------------------------------------------------------------------------------------------------------------------------|
| Fluency                     | 5     | Moderate | Students were able to generate several relevant mathematical ideas, although the variety of responses was still limited. |
| Flexibility                 | 2     | Low      | Students had difficulty producing solutions using different strategies or perspectives.                                  |
| Novelty                     | 1     | Low      | Students had limited ability to produce original or uncommon mathematical ideas.                                         |

These findings highlight greater difficulties in flexibility and novelty, particularly in generating solutions from different strategies or perspectives and producing original mathematical ideas. The pattern underscores the need for learning experiences that explicitly engage students in exploring alternative solution strategies, modifying mathematical situations, and generating original ideas. A structured instructional approach that provides sustained opportunities for such activities is therefore warranted, particularly in elementary mathematics education.

Problem posing has been identified as an instructional approach that can support students' mathematical creative thinking [15] [16]. Unlike conventional problem-solving activities, problem posing engages students in formulating and generating mathematical problems from given situations, positioning them as active producers of mathematical ideas [17] [18]. Such activities require students to generate ideas, modify problem conditions, and consider alternative possibilities, processes that are closely related to fluency, flexibility, and novelty in mathematical creative thinking [19]. When problem posing is conducted collaboratively, students can further exchange ideas, negotiate meanings,

provide feedback, and build upon one another's mathematical thinking [20] [21].

From a sociocultural perspective, the above interactions are consistent with Vygotsky's Zone of Proximal Development (ZPD), which provides the primary theoretical rationale for collaborative problem posing by emphasizing social interaction and scaffolding in supporting learning beyond what students may accomplish independently [7]. In collaborative problem-posing activities, peer interaction can therefore provide opportunities for students to encounter alternative perspectives, refine emerging ideas, and develop mathematical problems in different and potentially more original ways. Previous empirical studies have reported that collaborative problem posing can support the development of creative thinking, particularly in aspects related to flexibility and novelty [22] [23]. Thus, collaborative problem posing offers a theoretically grounded and empirically supported approach for addressing the uneven development of mathematical creative thinking identified in the preliminary assessment.

Although collaborative problem posing offers a potentially useful approach for developing mathematical creative thinking, its classroom implementation can benefit from instructional media that systematically supports collaborative activities and captures students' evolving ideas. As digital technologies become increasingly integrated into elementary mathematics education, web-based learning media have been used to facilitate interactive and student-centered learning experiences [24]. One such medium is the web-based E-LKPD (electronic student worksheet), which can integrate accessible learning materials, open-ended tasks, collaborative discussions, and opportunities for teachers to monitor students' work and provide feedback [25] [26]. These affordances make web-based E-LKPD a potentially suitable medium for supporting collaborative problem-posing activities.

However, several existing E-LKPDs used in elementary mathematics learning remain oriented toward routine and procedural problem-solving activities rather than problem posing and creative thinking [27] [28]. Their activities typically provide structured instructions and closed-ended or predetermined tasks, thereby offering limited opportunities for students to formulate, modify, and explore mathematical problems. Although some E-LKPDs incorporate collaborative features, these features are generally limited to discussion or communication functions but do not provide a systematic workflow through which students can exchange ideas, provide feedback on peers' problems, and collaboratively construct or modify mathematical problems. This limitation is particularly relevant to collaborative problem posing, in which idea exchange, peer feedback, and negotiation of mathematical meanings can provide opportunities for students to consider alternative perspectives and refine their ideas [22] [23]. Therefore, there remains a need for digital learning media that not only facilitates collaboration but also systematically integrates the processes of problem generation, peer interaction, feedback, and problem modification to support the development of mathematical creative thinking.

Based on the preceding discussion, a specific theoretical and empirical gap remains in the literature. Previous research has established the potential of problem posing and collaborative learning to support mathematical creative thinking and has demonstrated the potential of web-based E-LKPDs to facilitate mathematics learning [29] [30]. However, it remains unclear whether embedding collaborative problem-posing processes within a web-based E-LKPD provides additional instructional value beyond conventional E-LKPD-based instruction. This distinction is theoretically important because the use of digital technology alone does not necessarily foster mathematical creative thinking. Rather, its educational potential may depend on whether the learning environment systematically engages students in cognitively and socially demanding processes, including generating multiple ideas, modifying problem conditions, exchanging and evaluating peers' ideas, and co-constructing alternative mathematical problems. These processes are closely aligned with the development of fluency, flexibility, and novelty, suggesting that the effectiveness of a digital learning environment depends not only on its technological affordances but also on how those affordances are deliberately

designed to structure creative and collaborative learning processes.

Addressing this gap requires examining whether a web-based learning environment that explicitly operationalizes collaborative problem posing can provide greater benefits for mathematical creative thinking than conventional E-LKPD instruction. The present study addresses this gap by examining the effectiveness of COLLAPOSE (Collaborative Problem Posing E-LKPD), a web-based E-LKPD developed to facilitate collaborative problem posing in elementary mathematics learning.

Unlike conventional E-LKPDs that primarily emphasize procedural problem solving, COLLAPOSE incorporates structured activity sequences and instructional scaffolding to engage students in learning processes associated with three dimensions of mathematical creative thinking: fluency, flexibility, and novelty. Consistent with Cognitive Load Theory, the structured scaffolding is intended to manage unnecessary cognitive demands and direct students' attention toward task-relevant processes involved in generating, evaluating, and modifying mathematical problems [31] [32].

In addition, COLLAPOSE incorporates collaborative features, including discussion spaces, peer feedback on posed problems, and opportunities for students to modify and co-develop mathematical problems within groups. These features are intended to support the social and cognitive processes underlying collaborative problem posing while providing structured opportunities for students to develop mathematical creative thinking. Accordingly, this study aims to determine whether the use of COLLAPOSE produces greater improvement in elementary students' mathematical creative thinking than conventional E-LKPD instruction.

## 2. Methods

This study employed a quantitative approach with a quasi-experimental nonequivalent control group design. These two intact groups were involved: an experimental group and a control group. Both groups completed a pretest to assess their baseline level of mathematical creative thinking. The experimental group subsequently received instruction using the web-based COLLAPOSE E-LKPD, whereas the control group received instruction using a conventional E-LKPD that was non-web-based and did not incorporate collaborative problem-posing features. The intervention was conducted over four sessions, with each session lasting 90 minutes. After the intervention, both groups completed a posttest using the same instrument to assess changes in their mathematical creative thinking. This design was selected because it enabled the effectiveness of the COLLAPOSE E-LKPD to be examined in an authentic classroom setting without random assignment of individual students, consistent with the characteristics of research conducted in intact classroom settings [33] [34] [35].

The participants were 48 fifth-grade students at SDN Geluran 3, Sidoarjo, Indonesia. Participant selection was informed by a preliminary study conducted at the same school in 2025. During the preliminary study, a Mathematics Ability Test (Tes Kemampuan Matematika/TKM) was administered to identify students' levels of mathematical ability. The TKM results were used to establish heterogeneous student groupings comprising students with different levels of mathematical ability. These groupings had been established before the present study and were maintained throughout the implementation of the collaborative problem-posing activities.

Purposive sampling was employed to select the participating classes based on characteristics identified in the preliminary study. The selection criteria included heterogeneous student composition based on the TKM results, relatively comparable mathematics performance between the classes, and teacher recommendations regarding the suitability of the classes for the study. Two intact classes comprising 48 students in total were selected. One class ( $n = 24$ ) was designated as the experimental group, while the other class ( $n = 24$ ) was designated as the control group.

The experimental group received mathematics instruction using the web-based COLLAPOSE E-

LKPD, whereas the control group received instruction using a conventional E-LKPD that was non-web-based and did not incorporate collaborative problem-posing features. Random assignment of individual students was not feasible because the existing classroom structures had to be maintained in accordance with school regulations. To minimize variation attributable to teacher-related instructional practices, the same mathematics teacher taught both groups.

Because purposive sampling and intact classes were used, potential selection bias cannot be completely excluded. Accordingly, the findings should be interpreted within the context of the selected school and participant characteristics. The sample of 48 students represents a small-scale effectiveness trial conducted at this stage of the research. The study was intended to provide initial empirical evidence regarding the effectiveness of the developed COLLAPOSE E-LKPD before its evaluation in a larger-scale trial. A broader field trial involving a larger and more diverse sample is planned as a subsequent stage of the research roadmap [36].

An essay test measuring mathematical creative thinking was used as the research instrument. The test was developed based on three indicators of mathematical creative thinking: (1) fluency, defined as the ability to generate multiple relevant ideas or solutions; (2) flexibility, defined as the ability to approach problems from different perspectives and generate varied solutions; and (3) novelty, defined as the ability to generate distinctive, unusual, or original ideas or solutions [35] [36]. The instrument consisted of two main open-ended questions, each comprising three sub-questions (1a, 1b, and 1c for the first question and 2a, 2b, and 2c for the second question). The item structure was designed to allow the three indicators of mathematical creative thinking to be assessed comprehensively.

Different but equivalent sets of open-ended items were administered in the pretest and posttest. Although the items were different, both sets covered the same mathematical content, namely addition and subtraction of fractions, and were designed to have comparable levels of difficulty. Both sets assessed the same three dimensions of mathematical creative thinking: fluency, flexibility, and novelty. The use of different but equivalent items was intended to maintain comparability of the measured construct while minimizing potential testing or practice effects associated with repeated exposure to identical questions.

To establish content validity, the instrument was reviewed by five experts, consisting of three doctoral-level lecturers in mathematics education and two elementary school teachers holding master's degrees in elementary education with a concentration in mathematics. The expert review covered three aspects: (1) material appropriateness, including the alignment of item content with the fifth-grade level, curriculum competencies, and the test blueprint; (2) item construction, including the clarity of prompts in eliciting open-ended responses and the avoidance of ambiguity or multiple interpretations; and (3) language quality, including the use of clear, communicative, age-appropriate language and adherence to appropriate Indonesian language conventions. Based on the experts' feedback, minor revisions were made to the wording of several items to improve clarity and age appropriateness.

The revised instrument was subsequently pilot-tested with 15 fifth-grade students who were not included in the main study. The pilot testing was conducted to examine the empirical characteristics of the items and the internal consistency of the instrument before its use in the main study. To assess empirical item validity, the instrument was examined using the Corrected Item–Total Correlation, which assesses the correlation between each item score and the total test score. With a sample size of 15 students and a significance level of  $\alpha = 0.05$ , the critical  $r$ -value was 0.514 ( $df = 13$ ). An item was considered valid when its Corrected Item–Total Correlation exceeded the critical  $r$ -value of 0.514 [33] [34] [35]. The results of the validity test are presented in Table 2.

**Table 2.** Results of the Empirical Item Validity Test

| Item No. | Corrected Item–Total Correlation | r-table ( $n = 15, \alpha = 0.05$ ) | Validity Decision |
|----------|----------------------------------|-------------------------------------|-------------------|
| 1a.      | 0.6604                           | 0.514                               | Valid             |
| 1b.      | 0.5750                           | 0.514                               | Valid             |
| 1c.      | 0.6220                           | 0.514                               | Valid             |
| 2a.      | 0.6873                           | 0.514                               | Valid             |
| 2b.      | 0.6702                           | 0.514                               | Valid             |
| 2c.      | 0.6863                           | 0.514                               | Valid             |

As shown in Table 2, the Corrected Item–Total Correlation coefficients for the six items (1a through 2c) ranged from 0.5750 to 0.6873. Using a critical value of 0.514 for 15 respondents at a significance level of 0.05, all items showed correlation coefficients above the required threshold, indicating that each item was valid. Therefore, the six items were considered suitable for measuring students’ mathematical creative thinking abilities. After the validity test, the internal consistency of the instrument was examined using Cronbach’s Alpha coefficient to determine the consistency among the six items. The reliability analysis yielded a Cronbach’s Alpha coefficient of 0.862, which exceeds the commonly accepted threshold of 0.70 [37] [38], indicating that the instrument has good internal consistency and the six items demonstrated good internal consistency in the pilot sample. Within the pilot sample, the six items demonstrated satisfactory internal consistency. The results of the reliability analysis are presented in Table 3.

**Table 3.** Results of the Instrument Reliability Test

| Cronbach’s Alpha | N of Items |
|------------------|------------|
| 0.862            | 6          |

After the validity and reliability of the instrument had been established, data collection was carried out. The data collection procedure consisted of administering a mathematical creative thinking test on two separate occasions: a pretest and a posttest. The pretest was administered before the treatment to measure the students’ initial levels of mathematical creative thinking in both the experimental and control groups. Following the completion of the treatment sessions, the posttest was administered to assess changes in students’ mathematical creative thinking after the instructional intervention [33] [34] [35].

The pretest was administered concurrently to the experimental and control groups during the first week of the study, with a time allocation of 90 minutes. At this stage, students worked individually on six open-ended questions without assistance from the teacher or their peers. Following the pretest, the experimental group participated in four instructional sessions using the web-based COLLAPOSE E-LKPD, with each session lasting 90 minutes. In each session, students worked collaboratively in small groups of three to pose mathematical problems, provide feedback on peers’ problems, and modify problems through the COLLAPOSE platform. Meanwhile, the control group received instruction covering the same mathematical topics and using the same time allocation, but with a conventional E-LKPD that was non-web-based and did not incorporate collaborative problem-posing features. Following the completion of the four instructional sessions, the posttest was administered to both groups with a time allocation of 90 minutes.

The quantitative pretest and posttest data from both groups were analyzed statistically. Before conducting the hypothesis test, the assumptions of normality and homogeneity of variance were ex-

amined. The Shapiro–Wilk test was used to assess the normality of the data because the number of students in each group was less than 50 ( $n = 24$ ). A p-value greater than 0.05 was interpreted as indicating that the data did not significantly deviate from a normal distribution. Homogeneity of variance between the experimental and control groups was assessed using Levene’s test, with a p-value greater than 0.05 indicating homogeneous variances [39] [40] [37].

Following the assumption tests, an Independent Samples t-test was conducted to examine whether a statistically significant difference existed between the experimental and control groups in mathematical creative thinking performance. The test was selected because the study involved two independent groups and the data met the assumptions of normality and homogeneity of variance. The null hypothesis was rejected when the p-value was less than 0.05, indicating a statistically significant difference between the two groups [37] [38]. In addition, the magnitude of the improvement in mathematical creative thinking was examined using normalized gain (N-Gain), which was calculated from the pretest and posttest scores. In addition, Cohen’s d was calculated to estimate the magnitude of the difference in posttest mathematical creative thinking scores between the experimental and control groups. Cohen’s d was calculated by dividing the difference between the two group means by the pooled standard deviation. Effect sizes of approximately 0.20, 0.50, and 0.80 were interpreted as small, moderate, and large, respectively [41].

### 3. Results and Discussion

#### 3.1 Results

The study involved 48 fifth-grade students, with 24 students in the experimental group and 24 in the control group. Descriptive statistics for students’ mathematical creative thinking scores at pretest and posttest are presented in Table 4.

**Table 4.** Descriptive Statistics of the Pretest and Posttest Results for Students’ Mathematical Creative Thinking

| Statistics         | Experimental Pretest | Experimental Post-test | Control Pretest | Control Post-test |
|--------------------|----------------------|------------------------|-----------------|-------------------|
| N                  | 24                   | 24                     | 24              | 24                |
| Valid              | 24                   | 24                     | 24              | 24                |
| Missing            | 0                    | 0                      | 0               | 0                 |
| Mean               | 58.75                | 82.33                  | 59.12           | 67.46             |
| Std. Error of Mean | 1.892                | 1.456                  | 1.923           | 1.678             |
| Median             | 59.00                | 83.00                  | 60.00           | 68.00             |
| Variance           | 85.89                | 50.91                  | 88.73           | 67.59             |
| Range              | 42                   | 38                     | 44              | 41                |
| Minimum            | 38                   | 62                     | 37              | 45                |
| Maximum            | 80                   | 100                    | 81              | 86                |
| Sum                | 1410                 | 1976                   | 1419            | 1619              |

To assess baseline comparability between the experimental and control groups, we conducted an independent-samples t-test to compare their pretest scores, as shown in Table 5.

**Table 5.** Independent Samples t-Test of Pretest Scores

| Data    | <i>t</i> | <i>df</i> | Sig. (2-tailed) | Mean Difference | Std. Error Difference |
|---------|----------|-----------|-----------------|-----------------|-----------------------|
| Pretest | -0.140   | 46        | 0.890           | -0.375          | 2.679                 |

As shown in Table 5, the Independent Samples t-test yielded a *t*-value of  $-0.14$  with 46 degrees of freedom. The significance value (2-tailed) was 0.890, which exceeded the 0.05 significance level. Therefore, there was no statistically significant difference in pretest mathematical creative thinking scores between the experimental and control groups, indicating comparable baseline performance prior to the intervention.

The normality of the pretest and posttest scores was assessed using the Shapiro–Wilk test because each group consisted of fewer than 50 students ( $n = 24$ ). A *p*-value greater than 0.05 was interpreted as indicating that the normality assumption was met. The results are presented in Table 6.

**Table 6.** Result of the Shapiro-Wilk Normality Test

| Group        | Pretest   |           |       | Post-test |           |       |
|--------------|-----------|-----------|-------|-----------|-----------|-------|
|              | Statistic | <i>df</i> | Sig.  | Statistic | <i>df</i> | Sig.  |
| Experimental | 0.945     | 24        | 0.182 | 0.938     | 24        | 0.134 |
| Control      | 0.951     | 24        | 0.287 | 0.956     | 24        | 0.356 |

Before conducting the main hypothesis test, the assumptions of normality and homogeneity of variance were examined. The Shapiro–Wilk test was used to assess the normality of the pretest and posttest scores in each group. A *p*-value greater than 0.05 was interpreted as indicating that the normality assumption was met. The results are presented in Table 7.

**Table 7.** Levene's Test for Homogeneity of Variance Results

| Data     | Levene Statistic | <i>df1</i> | <i>df2</i> | Sig.  |
|----------|------------------|------------|------------|-------|
| Pretest  | 0.287            | 1          | 46         | 0.595 |
| Posttest | 0.423            | 1          | 46         | 0.519 |

As shown in Table 7, Levene's test indicated homogeneous variances for both the pretest ( $p = 0.595$ ) and posttest ( $p = 0.519$ ), as both significance values exceeded 0.05. To examine the magnitude of improvement in mathematical creative thinking, N-Gain was calculated and interpreted using Hake's (1999) classification: low ( $g < 0.30$ ), moderate ( $0.30 \leq g \leq 0.70$ ), and high ( $g > 0.70$ ). The results are presented in Table 8.

**Table 8.** N-Gain of Mathematical Creative Thinking Skills

| Group        | N  | Mean N-Gain | Category |
|--------------|----|-------------|----------|
| Experimental | 24 | 0.68        | Medium   |
| Control      | 24 | 0.21        | Low      |

The magnitude of the between-group difference was examined using Cohen's *d*. The calculated effect size was  $d = 1.62$ , which falls within the large-effect category according to Cohen's (1988) criteria,

with values of 0.20, 0.50, and 0.80 representing small, medium, and large effects, respectively. To examine the difference in post-test mathematical creative thinking scores between the experimental and control groups, an Independent Samples t-test was conducted. As shown in Table 9, the analysis yielded  $t(46) = 5.678$ ,  $p < .001$ , with a mean difference of 14.875 points. The experimental group obtained a higher post-test mean score ( $M = 82.33$ ) than the control group ( $M = 67.46$ ). Thus, the null hypothesis was rejected, indicating a statistically significant difference in post-test mathematical creative thinking scores between the two groups.

**Table 9.** Results of the Independent Samples t-Test on Posttest Scores

| Data      | <i>t</i> | <i>df</i> | Sig. (2-tailed) | Mean Difference | Std. Error Difference |
|-----------|----------|-----------|-----------------|-----------------|-----------------------|
| Post-test | 5.678    | 46        | 0.000           | 14.875          | 2.619                 |

As shown in Table 9, the post-test scores differed significantly between the experimental and control groups,  $t(46) = 5.678$ ,  $p < .001$ . The experimental group obtained a higher mean score ( $M = 82.33$ ) than the control group ( $M = 67.46$ ), with a mean difference of 14.875. The null hypothesis was therefore rejected. The between-group effect was large, with a Cohen's *d* of 1.94.

### 3.2 Discussion

The findings of this study indicate that the web-based E-LKPD COLLAPOSE, which integrates collaborative problem posing, can support the development of elementary students' mathematical creative thinking. Students in the experimental group demonstrated greater improvement than those in the control group, as reflected in the higher posttest performance and large between-group effect size (Cohen's *d* = 1.94). These findings suggest that the potential contribution of COLLAPOSE lies not merely in its web-based format, but in its integration of collaborative problem posing with structured opportunities for students to generate, exchange, and refine mathematical ideas. The findings are further interpreted through complementary theoretical perspectives, with Vygotsky's Zone of Proximal Development serving as the primary framework for explaining the role of social interaction and scaffolding in the development of mathematical creative thinking.

The experimental group demonstrated a moderate N-Gain ( $g = 0.68$ ), whereas the control group demonstrated a low N-Gain ( $g = 0.21$ ). This difference can be interpreted from the perspective of Vygotsky's (1978) Zone of Proximal Development (ZPD) [7] [21] [42]. Through COLLAPOSE, students engaged collaboratively in generating mathematical problems, exchanging peer feedback, and revising their ideas, thereby creating opportunities for learning through interaction with peers with different levels of mathematical ability. Such interaction is consistent with the ZPD perspective, which emphasizes the role of social interaction and scaffolding in supporting learning. Nevertheless, the moderate rather than high N-Gain observed in the experimental group suggests that improvements in mathematical creative thinking may require sustained instructional exposure, particularly in developing novelty. Previous studies have indicated that novelty involves complex cognitive processes that may develop through prolonged opportunities for cognitive restructuring and intensive instructional support [4] [15].

In contrast, the low N-Gain observed in the control group may be associated with the more procedural orientation of conventional E-LKPD activities, which provides fewer opportunities for students to formulate, modify, and explore mathematical problems. This finding is consistent with previous research highlighting the limitations of routine problem-posing activities in fostering flexibility and novelty in mathematical creative thinking [43]. Taken together, these findings suggest that the greater improvement observed in the experimental group may be related not simply to the use of

a digital learning medium, but to the integration of collaborative problem posing, peer interaction, and structured opportunities for students to generate and revise mathematical ideas.

The significant difference between the experimental and control groups,  $t(46) = 5.678$ ,  $p < .001$ , further supports the potential of collaborative problem posing as an instructional approach for developing mathematical creative thinking. From the perspective of Bandura's Social Cognitive Theory, this finding can be understood through reciprocal interactions among personal, behavioral, and environmental factors [44] [45]. Within COLLAPOSE, the web-based environment provides opportunities for students to observe peers' problem-posing strategies, exchange feedback, and revise their own ideas. These processes may facilitate learning through observation and social interaction, allowing students to adjust and extend their mathematical responses. This interpretation is consistent with research showing that positive interdependence and promotive interaction in collaborative learning are associated with improved higher-order thinking outcomes [20] [46]. Thus, Bandura's perspective complements the ZPD framework by highlighting how peer modeling and feedback within the learning environment may contribute to students' development of creative mathematical ideas.

The large between-group effect (Cohen's  $d = 1.94$ ) suggests that the difference in mathematical creative thinking was not only statistically significant but also substantial within the context of this study. This finding can be further interpreted through Cognitive Load Theory [31] [32]. Collaborative problem posing requires students to generate problems, evaluate mathematical relationships, consider alternative possibilities, and respond to peers' ideas, which may place considerable demands on working memory. The structured design of COLLAPOSE may help manage unnecessary cognitive demands by organizing these activities into sequential stages and providing prompts, examples, and documented peer feedback. Such scaffolding may allow students to allocate greater cognitive resources to creative processes, including generating multiple ideas, considering different perspectives, and developing original mathematical problems. This interpretation is consistent with research indicating that well-designed digital scaffolding can support learners when engaging in cognitively demanding tasks [47] [48].

A further theoretical implication concerns the role of indicator-specific scaffolding in supporting different dimensions of mathematical creative thinking. Consistent with Guilford's (1967) and Torrance's (1972) conceptualizations of creativity as a multidimensional construct [49] [50], COLLAPOSE provides scaffolding that is aligned with fluency, flexibility, and novelty. For fluency, students are encouraged to generate multiple mathematical problems from a given situation; for flexibility, they are guided to modify contexts or numerical information to produce different problem variations; and for novelty, they are encouraged to develop problems that differ from those generated by their peers.

By explicitly directing students' attention to the different forms of creative production, COLLAPOSE can provide more focused opportunities to practice each dimension within the collaborative problem-posing process. This mechanism can help explain the greater improvement observed in the experimental group, particularly given that the preliminary assessment identified flexibility and novelty as weaker areas. In contrast, conventional E-LKPD activities tend to emphasize repeated procedural practice, which may provide fewer opportunities for students to deliberately develop flexible and original mathematical ideas [14] [30]. These findings support the view that mathematical creativity can be fostered through appropriately designed instructional experiences rather than being treated solely as a fixed or innate characteristic [8] [9].

The findings of this study extend and complement our previous research on collaborative problem posing in elementary mathematics. In an earlier qualitative study, we found that although collaboration supported students' creative thinking, novelty remained particularly challenging for students to develop [22]. Our subsequent investigation of creative thinking in homogeneous student groups

further showed that fluency was relatively strong, whereas flexibility and novelty were constrained by group dynamics, particularly when discussion was dominated by one or two members [23]. These findings highlighted the need for a more systematically designed learning environment that could provide explicit support for novelty while promoting more equitable participation. The present study addresses this need through COLLAPOSE, a web-based E-LKPD that incorporates structured collaborative problem-posing activities and indicator-specific scaffolding. The greater improvement observed in the experimental group, together with the large between-group effect (Cohen's  $d = 1.94$ ), suggests that the design features of COLLAPOSE may have helped address limitations identified in the earlier studies. Thus, the present findings strengthen the continuity of our research trajectory by extending qualitative evidence on collaborative problem posing into the development and empirical evaluation of a digital instructional intervention.

The effectiveness of collaborative problem posing has been examined in previous empirical studies, although the reported outcomes and technological approaches have varied. For example, the U-Decimal study demonstrated that collaborative problem solving and problem posing supported by a ubiquitous learning application improved students' decimal learning achievement, with features such as multimedia explanations and peer assessment contributing to the learning process [51]. Similarly, a mobile learning study reported that problem-posing-based learning improved learning achievement, local cultural identity, and group learning self-efficacy [52]. The Crowdlearning paradigm likewise demonstrated the potential of collaborative problem generation, although its primary focus was on crowdsourced problem-bank development for assessment purposes [53].

These studies provide evidence of the potential of technology-mediated collaborative problem posing while differing from the present study in both their primary outcomes and instructional designs. Previous research has primarily focused on content achievement, self-efficacy, or assessment-oriented applications, whereas the present study specifically examines mathematical creative thinking. Moreover, COLLAPOSE integrates indicator-specific scaffolding targeting three dimensions of mathematical creative thinking—fluency, flexibility, and novelty—within a structured collaborative problem-posing process. Accordingly, the present study extends this body of research by examining a digitally mediated collaborative problem-posing environment specifically designed to support the development of mathematical creative thinking among elementary school students [10] [49].

When taken together, the previous studies have established the potential of web-based learning [54] [55] [56] and problem-posing strategies [57] [58] [59] to enhance various learning outcomes. However, the intersection of collaborative problem posing, web-based learning, and mathematical creative thinking at the elementary school level remains relatively underexplored. The present study addresses this gap by providing empirical evidence on COLLAPOSE, a web-based E-LKPD that integrates structured collaborative problem-posing activities with indicator-specific scaffolding for fluency, flexibility, and novelty. The findings extend the existing literature by showing that collaborative problem posing can be operationalized within a web-based learning environment to support the development of mathematical creative thinking among elementary students. The large between-group effect observed in this study (Cohen's  $d = 1.94$ ) further indicates a substantial difference in mathematical creative thinking performance within the specific context of the participating students and intervention. Thus, the contribution of this study lies not simply in the use of web-based technology, but in the integration of digital affordances, collaborative problem posing, and targeted creative-thinking scaffolding within a single instructional environment.

The findings of this study have theoretical, practical, and policy implications. From a theoretical perspective, the study provides empirical support for understanding collaborative problem posing through complementary theoretical perspectives. In particular, the findings are consistent with Bandura's Social Cognitive Theory, suggesting that peer modeling, feedback, and interaction within a digital learning environment may contribute to the development of mathematical creative thinking

[44] [45]. The findings also provide additional support for the application of Cognitive Load Theory to the design of web-based learning environments, particularly the use of structured scaffolding to organize cognitively demanding creative tasks [31]. These perspectives complement the primary ZPD framework by highlighting the behavioral and cognitive mechanisms that may operate within collaborative digital learning.

From a practical perspective, COLLAPOSE provides an example of how web-based E-LKPDs can integrate collaborative problem posing with explicit scaffolding for fluency, flexibility, and novelty. The structured activity flow may assist teachers in organizing collaborative mathematical activities while allowing them to focus on facilitating discussion, feedback, and students' mathematical reasoning [60] [61]. However, implementation may still require teacher preparation, adequate digital access, and contextual adaptation to students' and schools' needs.

From a policy and curriculum perspective, the findings are relevant to the emphasis on creativity and higher-order competencies in Indonesia's Kurikulum Merdeka [11] [62]. The evidence from this small-scale study suggests that digitally mediated collaborative problem posing may be a promising approach for supporting mathematical creative thinking at the elementary level. Rather than providing evidence for immediate large-scale adoption, the findings offer an initial empirical basis for further testing across more diverse schools, student populations, and implementation contexts. More broadly, the design principles underlying COLLAPOSE may inform future development of digital mathematics learning environments that integrate collaborative interaction, structured scaffolding, and creative-thinking processes.

Several directions may be pursued in future research. First, longitudinal studies could examine whether improvements in mathematical creative thinking are sustained beyond the intervention period and whether continued exposure to collaborative problem posing produces further development over time. Second, cross-cultural and multi-site studies could investigate how differences in classroom practices, collaborative norms, and mathematical learning cultures influence the implementation and effectiveness of COLLAPOSE. Third, artificial intelligence could be explored to provide more adaptive scaffolding and feedback based on students' problem-posing processes and emerging learning needs [63]. Such systems could potentially adjust prompts or feedback dynamically while maintaining the collaborative nature of the learning process. Finally, qualitative microgenetic studies could provide a more detailed account of how individual students' mathematical creative thinking develops over time, particularly how they progress from generating relatively simple problems to producing increasingly flexible and novel mathematical ideas.

Several limitations should be considered when interpreting the findings of this study. First, the study involved a relatively small sample of 48 fifth-grade students from a single elementary school. Although the use of intact classes was appropriate for the quasi-experimental design, the findings may not be directly generalizable to students from different schools, regions, or educational contexts. Second, individual students were not randomly assigned to the experimental and control groups because the study was conducted using existing classroom structures. Although the groups were selected based on comparable characteristics and prior mathematics ability, potential selection bias cannot be completely excluded.

Third, besides the two above, the intervention was implemented over six sessions, consisting of two assessment sessions and four intervention sessions of 90 minutes each. This relatively short intervention period may have limited the extent to which students could fully internalize more complex aspects of mathematical creative thinking, particularly novelty. Fourth, mathematical creative thinking was assessed primarily through written open-ended essay tasks measuring fluency, flexibility, and novelty. Although these measures provide direct evidence of students' creative thinking performance, they do not fully capture the dynamic cognitive and social processes occurring during

collaborative problem-posing activities.

Finally, the present design evaluated COLLAPOSE as an integrated instructional intervention. Consequently, the effects of individual components, such as web-based delivery, collaborative problem posing, peer feedback, and indicator-specific scaffolding, could not be isolated separately. Therefore, the observed effects should be interpreted as the overall effect of the COLLAPOSE intervention rather than the independent contribution of any single feature. These limitations provide important directions for future research involving larger and more diverse samples, longer intervention periods, and designs capable of examining the contribution of individual COLLAPOSE features.

## 4. Conclusion

## 5. Conclusion

This study examined the effectiveness of the web-based E-LKPD COLLAPOSE, which integrates collaborative problem posing and indicator-specific scaffolding to support elementary students' mathematical creative thinking. The findings indicated greater improvement in mathematical creative thinking among students who used COLLAPOSE than among those who received conventional E-LKPD instruction. The experimental group demonstrated a moderate N-Gain ( $g = 0.68$ ), compared with a low N-Gain in the control group ( $g = 0.21$ ). The difference in posttest performance was statistically significant,  $t(46) = 5.678$ ,  $p < .001$ , with a large between-group effect. These findings suggest that integrating collaborative interaction, peer feedback, problem modification, and targeted scaffolding may provide a promising instructional approach for engaging students in generating, varying, and developing mathematical ideas.

Within the context of the participating fifth-grade students and the six-session intervention, COLLAPOSE provides an alternative digital learning environment for incorporating collaborative problem posing into elementary mathematics instruction. However, the findings should be interpreted within the scope of the study and should not be generalized to broader populations without further evidence, given the small sample, single-school setting, purposive sampling, and quasi-experimental design. Future research should examine COLLAPOSE with larger and more diverse samples, longer intervention periods, and component-level comparisons to establish the generalizability and sustainability of its effects and to determine the specific contributions of its collaborative problem-posing and scaffolding components.

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