CJPE: *Cokroaminoto Journal of Primary Education*
https://e-journal.my.id/cjpe
Volume 9 | Nomor 4 | Desember |2026
e-ISSN: 2654-6434 dan p-ISSN: 2654-6426



Enhancing Mathematical Conceptual Understanding Through Discovery Learning and M-ESCAPE

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Keywords *:*
Discovery Learning,
Media M-ESCAPE,
Mathematical Conceptual Understanding.

Abstract*. Conceptual understanding forms the foundation for mastering number operations. However, mathematics instruction in fifth-grade classrooms tends to be teacher-centered and limited in the use of concrete media, resulting in suboptimal student understanding of mathematical concepts. This study aims to enhance the mathematical conceptual understanding of fifth-grade students using the Discovery Learning model supported by M-ESCAPE media, focusing on operations involving whole numbers up to 100,000. The study employs the Classroom Action Research model developed by Kemmis and McTaggart, conducted over two cycles with 17 fifth-grade students at SD Negeri 1 Prambatan Lor as subjects. Each cycle followed the stages of planning, implementation, observation, and reflection. Data were collected through tests, interviews, and observations, and the test data were analyzed using quantitative descriptive methods based on average scores, classical mastery, and the achievement of specific conceptual understanding indicators. The results indicate that the average score increased from 59.56 in the pre-cycle stage to 67.40 in Cycle I and 81.62 in Cycle II. Classical mastery rose from 35.29% in the pre-cycle stage to 41.18% in Cycle I and 100% in Cycle II. Thus, the implementation of the Discovery Learning model supported by M-ESCAPE media can improve students' mathematical conceptual understanding regarding whole number operations.*

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Introduction

Mathematics education plays an essential role in developing students' analytical, critical, logical, and creative thinking. Beyond computational accuracy, meaningful mathematics learning requires students to understand the principles underlying mathematical operations, establish relationships among concepts, and apply their knowledge to solve contextual problems. These competencies are particularly important in elementary education because foundational numerical knowledge supports the development of more advanced mathematical understanding. Whole-number operations, for instance, involve more than executing written calculation algorithms.

Conceptual understanding requires students to interpret the meaning of operations,

distinguish when regrouping or borrowing is necessary, translate contextual situations into mathematical expressions, select appropriate procedures, and apply these procedures to word problems. Difficulties in coordinating these competencies may prevent students from solving problems successfully even when they are familiar with the relevant calculation procedures. Research on mathematics learning has demonstrated that game-based environments can support numerical knowledge and arithmetic proficiency, although their effectiveness varies across instructional designs and learning outcomes (Brezovszky et al., 2019; Tokac et al., 2019). Conceptual understanding should therefore be treated as a central learning outcome rather than inferred solely from students' ability to produce correct numerical answers.

The need to strengthen conceptual understanding is evident in the mathematics classroom at SD Negeri 1 Prambatan Lor, particularly in Grade V instruction on whole-number operations. A preliminary assessment involving 17 students produced a mean score of 59.56, with only 6 students (35.29%) achieving the *Kriteria Ketercapaian Tujuan Pembelajaran* (KKTP), which was set at 75. Analysis of the assessment results further indicated that students' lowest performance occurred in the indicator of applying concepts or solving problems, at 30.88%, followed by selecting appropriate procedures or operations, at 52.94%. These findings indicate that students experienced particular difficulties connecting arithmetic knowledge with the demands of mathematical problems.

Classroom observations and interviews provided additional evidence concerning the instructional conditions associated with these difficulties. Mathematics lessons relied primarily on teacher explanations and subject textbooks, while student activities were dominated by assignments in student worksheets (*Lembar Kerja Siswa*, LKS). The teacher also reported that students struggled to determine appropriate operations and solve problems involving multiple steps. Opportunities to manipulate concrete materials, investigate mathematical relationships, and construct concepts through guided exploration had not been sufficiently incorporated into classroom activities. The convergence of the preliminary assessment, observations, and interviews indicates a need to strengthen instructional practices so that students can progress beyond procedural execution towards a more meaningful understanding of whole-number operations. One instructional consideration is the relationship between the abstract nature of mathematical concepts and the learning experiences provided to elementary school students. Whole-number operations involve numerical relationships that may not be immediately apparent when instruction focuses predominantly on symbolic notation and worked examples. Concrete materials and multiple representations can help students examine these relationships, provided that classroom activities explicitly connect practical experiences with mathematical reasoning.

A meta-analysis of mathematics instruction using concrete manipulatives found positive effects on learning outcomes compared with instruction relying exclusively on abstract mathematical symbols, although the magnitude of the effects varied according to instructional and methodological characteristics (Carbonneau et al., 2013). Research on tangible interfaces in primary mathematics has also examined how interactive resources can facilitate exploration and engagement with mathematical tasks (Zito et al., 2021). Classroom action research in primary mathematics has also addressed the limited availability of concrete learning media, using the Papan Kantong Pintar (PaKaPin) board to support Grade II students' conceptual understanding of geometry over two cycles (Afif et al., 2025). These findings suggest that instructional media should not be regarded

merely as supplementary classroom equipment. Their educational value depends on whether students are encouraged to explain their observations, compare solution strategies, and connect concrete experiences to mathematical representations. The instructional challenge at SD Negeri 1 Prambatan Lor is therefore not simply to introduce more engaging materials, but to organize learning experiences that enable students to investigate numerical relationships, select appropriate operations, and explain the reasoning underlying their solutions.

Discovery learning provides a pedagogical approach that may address this challenge by positioning students as active participants in constructing mathematical knowledge. Rather than relying exclusively on explanations supplied by the teacher, students engage in structured activities involving observation, information processing, identification of relationships, and the formulation of conclusions. This approach is relevant to whole-number operations because students need to understand why a particular operation is appropriate rather than merely memorize the steps used to perform it. Nevertheless, discovery learning should not be interpreted as unrestricted exploration or as an expectation that students independently discover every mathematical principle without assistance. A meta-analysis of discovery-based instruction found that unassisted discovery was generally less effective than explicit instruction, whereas enhanced or assisted discovery produced more favorable learning outcomes than comparison approaches (Alfieri et al., 2011). Similarly, a meta-analysis of inquiry-based learning found that guidance positively influenced learning activities, performance success, and learning outcomes (Lazonder & Harmsen, 2016). These findings support a structured approach in which students investigate mathematical relationships while receiving appropriate instructional guidance. Primary-school classroom action research has also applied discovery learning with supporting media: discovery learning assisted by flipbook media was reported to raise third-grade students' reading mastery from 64% in Cycle I to 74% in Cycle II, although that study addressed reading rather than mathematics (Cindyanawati et al., 2025). In the present study, discovery learning is implemented through sequenced activities and purposefully designed media intended to help students connect their observations to the mathematical concepts being learned.

Instructional media can strengthen discovery-oriented learning when they provide meaningful contexts for exploration and organize mathematical tasks into manageable activities. Game-based learning research has demonstrated potential benefits for mathematics achievement, numerical knowledge, and student engagement, although the magnitude and nature of these benefits vary across instructional designs and learning outcomes. A meta-analysis of mathematics game-based learning found heterogeneity in the magnitude and direction of effect sizes across studies, indicating that games should not be assumed to improve learning independently of their pedagogical implementation (Tokac et al., 2019). Research involving a game-based learning environment for primary students found benefits for adaptive number knowledge, illustrating the potential of structured mathematical games to support numerical development (Brezovszky et al., 2019).

A systematic review of non-digital mathematics games likewise examined their contribution to mathematical learning among primary school students, highlighting the relevance of considering game design and implementation when interpreting learning outcomes (Russo et al., 2024). Other reviews have examined the cognitive and affective outcomes associated with digital games and serious games, demonstrating that educational benefits depend on the interaction between game features, instructional

objectives, and learner characteristics (Clark et al., 2016; Connolly et al., 2012; Vankúš, 2021). These findings support the use of game-based media as a potential means of organizing mathematical exploration, but they also establish an important qualification: engagement and enjoyment are not sufficient evidence of conceptual learning.

Mission-based learning is particularly relevant to the difficulties identified in the preliminary assessment. Students who struggle to select appropriate operations or interpret multistep word problems may benefit from activities requiring them to process information, identify the mathematical demands of a task, and determine a suitable solution before progressing to the next challenge. Educational escape rooms provide an example of how mathematical tasks can be organized within a sequence of challenges that requires learners to apply mathematical ideas in contextualized situations. Research has examined escape rooms as an active methodology for mathematics learning and has reported improvements in achievement and selected affective outcomes in particular instructional settings (Fuentes-Cabrera et al., 2020). Educational escape rooms have also been investigated as tools for supporting mathematical activity and horizontal mathematization (Piñero Charlo, 2020). A study of escape-room technology in secondary mathematics education further examined its potential to support achievement, motivation, and learner autonomy, although its findings cannot automatically be generalized to elementary students or to conceptual understanding of whole-number operations (Alabdulaziz, 2023). The use of escape rooms in mathematics education has also been discussed as a way of organizing mathematical problems and collaborative challenges (Mačėnaitė, 2021; Stohlmann, 2023). Collectively, this literature provides a rationale for investigating a physical, mission-based medium that incorporates structured mathematical tasks. It does not, however, establish that every mission-based activity will improve conceptual understanding; the contribution of such a medium must be examined in relation to its mathematical content and instructional implementation.

The present study introduces Math Escape Adventure (M-ESCAPE), a mission-based instructional medium designed to support the implementation of discovery learning in Grade V mathematics. M-ESCAPE consists of an adventure-themed banner, mission cards, student worksheets (*Lembar Kerja Peserta Didik*, LKPD), an explorer passport, and an explorer certificate. At each station, students receive mission cards and worksheets that guide them through activities involving information processing and the discovery of concepts related to whole-number operations. The sequence is designed to correspond to the stages of discovery learning, beginning with an explorer story that serves as stimulation and concluding with an activity intended to consolidate students' understanding.

The medium organizes mathematical exploration into a coherent sequence of tasks in which students engage with mathematical information rather than merely follow prescribed calculation procedures. Its pedagogical rationale lies in the integration of a narrative context, mission-based progression, and structured opportunities for mathematical reasoning. The design is consistent with broader research on game-based mathematics learning, which emphasizes the importance of aligning game mechanics with the intended learning objectives rather than treating games as an independent source of educational benefit (Hung et al., 2014; Ke & Grabowski, 2007). The use of M-ESCAPE is therefore examined as part of an instructional intervention that combines discovery learning with a purposefully designed physical learning medium. Existing research provides a foundation for this instructional approach, but the available evidence addresses different combinations of learning models, media, mathematical content, and

educational outcomes. Research on concrete manipulatives has examined their contribution to mathematical learning relative to abstract instruction (Carbonneau et al., 2013).

While studies of digital games have investigated numerical knowledge, achievement, motivation, and other outcomes across different student populations (Brezovszky et al., 2019; Tokac et al., 2019; Vankúš, 2021). Research on educational escape rooms has examined mathematical activity and achievement, but evidence from secondary education or other instructional settings does not directly establish the effectiveness of a physical, mission-based medium for elementary students' conceptual understanding of whole-number operations (Alabdulaziz, 2023; Fuentes-Cabrera et al., 2020; Piñero Charlo, 2020). Research on discovery-oriented mathematics environments also indicates that the organization of learning tasks and the provision of appropriate guidance are important considerations in instructional design (Lazonder & Harmsen, 2016; Weinhandl et al., 2025). The unresolved issue is therefore how a structured, non-digital, mission-based medium integrated with discovery learning can support the specific conceptual demands of whole-number operations up to 100,000 in Grade V. The present study addresses this issue in the classroom context of SD Negeri 1 Prambatan Lor, where preliminary evidence identified difficulties in selecting appropriate operations and applying concepts to problem-solving tasks. Its contribution is a contextually grounded investigation of changes in students' mathematical conceptual understanding following the implementation of discovery learning assisted by M-ESCAPE.

The study seeks to answer the following question: How does the mathematical conceptual understanding of Grade V students at SD Negeri 1 Prambatan Lor improve after the implementation of discovery learning assisted by M-ESCAPE in learning whole-number operations up to 100,000? Accordingly, the objective is to describe the improvement in students' mathematical conceptual understanding through this instructional intervention. The study's novelty lies in integrating discovery learning with a physical, mission-based medium organized around sequential learning stations and aligned with the conceptual demands of whole-number operations up to 100,000, rather than claiming that discovery learning or game-based mathematics instruction is itself new.

Metode

Research Design

This study employed Classroom Action Research (CAR) using a quantitative descriptive approach to improve Grade V students' mathematical conceptual understanding of whole-number operations through discovery learning assisted by the M-ESCAPE learning medium. The study followed the reflective spiral model developed by Kemmis and McTaggart, comprising four stages in each cycle: planning, acting, observing, and reflecting (Machali, 2022). The research was conducted over two cycles, with the findings from Cycle I informing instructional improvements in Cycle II. During the planning stage, the researcher prepared the Deep Learning Lesson Plan (Rencana Pembelajaran Mendalam, RPM), Student Worksheets (Lembar Kerja Peserta Didik, LKPD), M-ESCAPE learning materials, and assessment instruments. The action stage involved implementing discovery learning assisted by M-ESCAPE. The observing stage involved collecting students' learning achievement data through assessments at the end of each cycle. During the reflection stage, students' test scores and written responses were

analyzed to evaluate the implementation of the intervention and identify aspects requiring improvement in the subsequent cycle. The intervention consisted of six meetings across two cycles, with three meetings per cycle, each lasting 70 minutes. Cycle I covered addition in Meeting 1, subtraction in Meeting 2, and addition- and subtraction-related problem-solving followed by the Cycle I assessment in Meeting 3. Cycle II covered multiplication in Meeting 4, division in Meeting 5, and multiplication- and division-related problem-solving followed by the Cycle II assessment in Meeting 6.

Research Setting, Location, and Period

The study was conducted in Grade V at SD Negeri 1 Prambatan Lor from August to September 2026. The research focused on students' conceptual understanding of whole-number operations up to 100,000. The instructional intervention integrated the discovery learning model with M-ESCAPE, an adventure-themed learning medium designed to guide students through structured group activities and concept-discovery tasks. M-ESCAPE consisted of an adventure-themed banner featuring a starting island, Station 1, Station 2, a treasure area, and a designated space for displaying explorer certificates. Supporting materials included mission cards and student worksheets for both stations, explorer passports stamped by the teacher upon completion of each station, explorer certificates, and star and ship stickers used to mark each group's progress. The intervention followed the six stages of discovery learning. During stimulation, the teacher introduced the adventure narrative and explained the M-ESCAPE activity sequence. During problem statement, students identified problems presented on the mission cards and formulated initial conjectures. During data collection, groups completed worksheets at Stations 1 and 2 and received teacher stamps upon completing each station. During data processing, students analyzed their worksheet responses and summarized their findings on explorer certificates. During verification, groups displayed their certificates on the banner and presented their findings. Finally, during generalization, students and the teacher formulated conclusions about the whole-number operation concepts addressed in the lessons.

Population and Sample

The target population comprised all Grade V students at SD Negeri 1 Prambatan Lor. The study included the entire class of 17 students, consisting of seven boys and ten girls. Accordingly, the sample comprised 17 students, with each student serving as a unit of analysis. No separate sample-size calculation was reported because the intervention was implemented with the entire class.

Sampling Technique and Sampling Criteria

All 17 Grade V students were included in the study, making the sample equivalent to the accessible classroom population. No additional respondent-selection criteria were reported. In Cycle I, students were assigned to homogeneous groups based on their pre-cycle test results. Following reflection on Cycle I, the grouping arrangement was revised for Cycle II. Students were then assigned to heterogeneous groups, with responsibilities distributed among group members. The designated roles were group leader, mission reader, recorder, and timekeeper or explorer. This adjustment was intended to support more balanced participation during collaborative learning activities.

Data Collection Techniques

Data were collected using test and non-test techniques. The primary quantitative data were obtained through written essay tests administered during the pre-cycle stage and at the end of Cycles I and II. These assessments measured students' conceptual

understanding of whole-number operations at the corresponding stages of the intervention. Supporting data were collected through a structured interview with the Grade V classroom teacher and classroom observations during the pre-cycle stage. The interview was conducted to obtain information about the initial learning conditions and students' mathematical conceptual understanding. Classroom observations were used to examine the mathematics teaching and learning process before the intervention. The interview and observation findings provided contextual information for identifying initial instructional challenges and planning the classroom action.

Research Instrument and Measurement

The primary research instrument was a written essay test comprising six questions at each assessment stage. The questions were developed based on six indicators of mathematical conceptual understanding adapted from Siahaan and Sihotang (2023): (1) restating a concept; (2) classifying objects according to properties consistent with a concept; (3) providing examples and non-examples of a concept; (4) representing a concept; (5) using, applying, and selecting appropriate procedures or operations; and (6) applying concepts to solve problems. The assessments were structured around the same six indicators, while their content was adjusted to the learning stage. The pre-cycle test covered all four arithmetic operations on whole numbers. The Cycle I test focused on addition and subtraction, whereas the Cycle II test focused on multiplication and division of whole numbers up to 100,000. Each question was scored on a scale of 0–4, producing a maximum total score of 24. Students' scores were converted to a 100-point scale by dividing the total score obtained by the maximum possible score and multiplying the result by 100.

The study used three principal assessment criteria: conceptual understanding, learning mastery, and improvement. Individual learning mastery was defined as achieving the school-established Minimum Learning Achievement Criterion (Kriteria Ketercapaian Tujuan Pembelajaran, KKTP) of 75. Classical learning mastery was defined as at least 80% of students meeting this individual criterion. Improvement was assessed by comparing mean scores and calculating the percentage increase between successive assessment stages. Student achievement was classified into five categories based on Mardatillah et al. (2023): very good (90–100), good (80–89), adequate (70–79), poor (60–69), and very poor (≤60). The intervention was considered successful when classical learning mastery reached at least 80% and the class mean fell within the good category. If these criteria were not met in Cycle I, instructional improvements were planned for Cycle II based on the reflection findings.

Data Analysis Techniques

The data were analyzed using descriptive quantitative techniques. Students' mathematical conceptual understanding was evaluated using individual test scores, class mean scores, classical learning mastery, and percentage improvement across the pre-cycle, Cycle I, and Cycle II assessments. Individual scores were calculated by dividing the score obtained by the maximum possible score and multiplying the result by 100. where S represents the student's final score, S_o is the score obtained, and $S_{\max}$ is the maximum possible score. The class mean was calculated by dividing the sum of all students' scores by the total number of students: where $\bar{X}$ denotes the class mean, $\sum X$ is the sum of individual student scores, and N is the total number of students.

Classical learning mastery was calculated as the percentage of students who achieved scores equal to or greater than the school-established Minimum Learning Achievement Criterion (KKTP) of 75. where P represents classical learning mastery, N_m is the number

of students achieving scores of at least 75, and N is the total number of students. The intervention was considered successful when classical learning mastery reached at least 80% and the class mean was within the good achievement category. The percentage improvement in the class mean between two consecutive assessment stages was calculated using the following formula. where I represents the percentage improvement, $\bar{X}_1$ is the mean score at the earlier assessment stage, and $\bar{X}_2$ is the mean score at the subsequent stage. The analysis compared mean scores, classical learning mastery, and achievement across the six conceptual-understanding indicators to evaluate progress from the pre-cycle to Cycle I and Cycle II. The findings were used to assess the achievement of the predetermined success criteria and guide instructional reflection between cycles.

Results and Discussion

Results

Baseline Performance in Mathematical Conceptual Understanding

The preliminary assessment was administered to 17 fifth-grade students at SD Negeri 1 Prambatan Lor to identify their initial level of mathematical conceptual understanding before the implementation of discovery learning assisted by the M-ESCAPE adventure-themed physical medium. The assessment covered six indicators of conceptual understanding and consisted of six essay questions scored on a scale of 0–4 per question. The total score was subsequently converted to a 100-point scale. Individual mastery was determined using the Minimum Competency Achievement Criterion (KKTP) of 75.

The preliminary results indicated that students' mathematical conceptual understanding was generally low. The class mean score was 59.56, categorized as very poor. Only 6 of the 17 students (35.29%) achieved the KKTP, whereas 11 students (64.71%) had not reached the required threshold. Individual scores ranged from 29.17 to 87.50, indicating considerable variation in students' initial performance. The distribution across achievement categories further illustrates this condition. Eight students were classified in the very poor category, one in the poor category, four in the adequate category, and four in the good category. No students reached the very good category. Although several students demonstrated relatively strong conceptual understanding, most had not achieved the expected level of competency before the intervention.

An examination of students' responses also identified difficulties in applying concepts to solve problems and selecting appropriate procedures or operations. Across seven students, 11 responses received a score of zero because the answers were either left blank or were irrelevant to the problem context. Five of these responses occurred in Indicator 6 (applying concepts to solve problems), four in Indicator 5 (using, applying, and selecting appropriate procedures or operations), and two in Indicator 1 (restating a concept). These response patterns provided a baseline for identifying the conceptual skills requiring further instructional attention.

Changes in Overall Mathematical Conceptual Understanding

The overall results were compared across the pre-cycle, Cycle I, and Cycle II to examine changes in students' mathematical conceptual understanding during the classroom action research. The comparison included the class mean, maximum and minimum scores, number of students meeting the KKTP, and classical mastery percentage.

Table 1. Overall Students' Mathematical Conceptual Understanding Across Research Stages

Assessment aspect	Pre-cycle	Cycle I	Cycle II	Increase (Pre-cycle–Cycle II)
Mean score	59.56	67.40	81.62	22.06 points
Maximum score	87.50	87.50	91.67	4.17 points
Minimum score	29.17	45.83	75.00	45.83 points
Students meeting KKTP	6	7	17	11 students
Classical mastery	35.29%	41.18%	100.00%	64.71 percentage points
Mean-score category	Very poor	Poor	Good	—

Note. KKTP = Minimum Competency Achievement Criterion, set at 75. Mean-score categories are reported separately from the distribution of individual students across achievement categories. Score increases are expressed in points, whereas the increase in classical mastery is expressed in percentage points. Table 1 shows a progressive increase in overall mathematical conceptual understanding across the three assessment stages. The mean score rose from 59.56 in the pre-cycle to 67.40 in Cycle I, an increase of 7.84 points. By the end of Cycle II, the mean had reached 81.62, representing a further increase of 14.22 points from Cycle I and a total increase of 22.06 points from the pre-cycle. The class mean consequently moved from the very poor category in the pre-cycle to the poor category in Cycle I and the good category in Cycle II.

The minimum score also increased at each stage, from 29.17 in the pre-cycle to 45.83 in Cycle I and 75.00 in Cycle II. The maximum score remained at 87.50 between the pre-cycle and Cycle I before increasing to 91.67 in Cycle II. These changes indicate that the improvement in the class mean was accompanied by an increase in the lowest observed score, rather than being limited to students with initially high scores. Classical mastery increased from 35.29% in the pre-cycle to 41.18% in Cycle I, corresponding to an increase from six to seven students meeting the KKTP. In Cycle II, all 17 students achieved scores of at least 75, resulting in 100% classical mastery. Overall, the number of students meeting the criterion increased by 11, while the classical mastery rate increased by 64.71 percentage points from the pre-cycle to Cycle II.

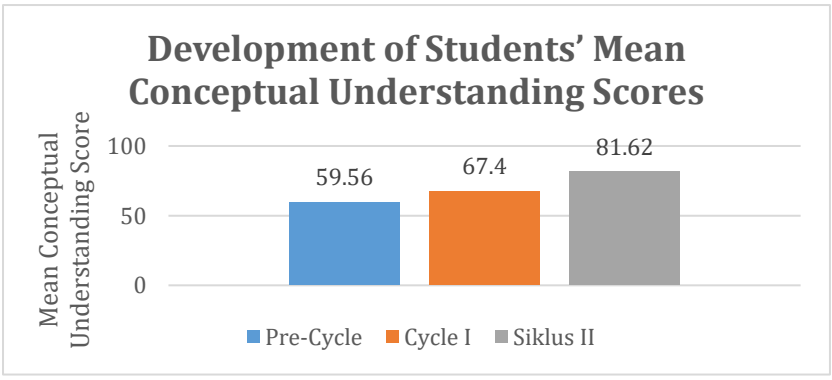


Figure 1. Mean scores of students' mathematical conceptual understanding across the pre-cycle, Cycle I, and Cycle II.

Figure 1 illustrates the changes in students' mean scores of mathematical conceptual understandings across the pre-cycle, Cycle I, and Cycle II. The mean score increased from 59.56 in the pre-cycle to 67.40 in Cycle I and 81.62 in Cycle II. This upward trend indicates an improvement in the overall class performance, with the largest increase occurring between Cycle I and Cycle II.

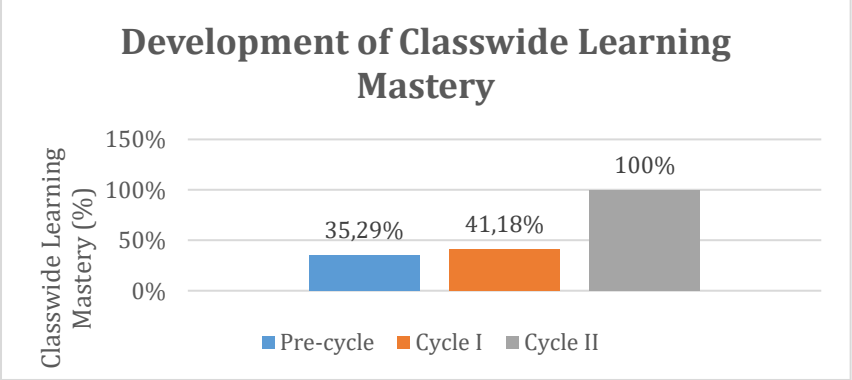


Figure 2. Classical mastery percentages across the pre-cycle, Cycle I, and Cycle II.

Figure 2 presents the percentage of students achieving the Minimum Competency Achievement Criterion (KKTP ≥ 75) across the three assessment stages. Classical mastery increased from 35.29% in the pre-cycle to 41.18% in Cycle I, before reaching 100% in Cycle II. These results indicate that all 17 students achieved the established competency criterion by the end of Cycle II.

Changes Across Mathematical Conceptual Understanding Indicators

The indicator-level analysis was conducted to identify which aspects of mathematical conceptual understanding showed the greatest and smallest changes throughout the research. The six indicators covered the ability to restate concepts, classify objects according to conceptual properties, provide examples and non-examples, represent concepts, select and apply appropriate procedures or operations, and apply concepts to solve problems.

Table 2. Students' Scores for Each Mathematical Conceptual Understanding Indicator

Indicator	Pre-cycle (%)	Cycle I (%)	Cycle II (%)	Increase (Pre-cycle–Cycle II)
1. Restating a concept	64.71	91.18	92.65	27.94 points
2. Classifying objects based on conceptual properties	75.00	80.88	80.88	5.88 points
3. Providing examples and non-examples	61.76	69.12	83.82	22.06 points
4. Representing a concept	72.06	77.94	91.18	19.12 points
5. Using, applying, and selecting appropriate procedures or operations	52.94	54.41	75.00	22.06 points
6. Applying concepts to solve problems	30.88	30.88	66.18	35.30 points

Note. Indicator scores are expressed as percentages. Increases are calculated from the displayed values and reported in percentage points. Accordingly, the increase for Indicator 6 is 35.30 points (66.18 − 30.88). Table 2 indicates that all six indicators had higher scores in Cycle II than in the pre-cycle. The largest increase occurred in Indicator 6, applying concepts to solve problems, which rose from 30.88% to 66.18%, an increase of 35.30 points. Despite this improvement, Indicator 6 remained the lowest-scoring indicator in Cycle II. Indicator 5, concerning the selection and application of appropriate procedures or operations, also improved, from 52.94% in the pre-cycle to 75.00% in Cycle II, an increase of 22.06 points.

Indicator 1, restating a concept, increased from 64.71% in the pre-cycle to 91.18% in Cycle I and 92.65% in Cycle II. Indicator 4, representing a concept, rose from 72.06% to 77.94% and then to 91.18%. Indicator 3, providing examples and non-examples,

increased from 61.76% to 69.12% and subsequently to 83.82%. These results show that the three indicators continued to improve between Cycle I and Cycle II. In contrast, Indicator 2, classifying objects based on properties consistent with a concept, increased from 75.00% in the pre-cycle to 80.88% in Cycle I but remained at 80.88% in Cycle II. Thus, its overall improvement was 5.88 points, the smallest increase among the six indicators. Although this indicator did not decline, its score did not improve further in the second cycle. Overall, the indicator-level results show that the greatest gains occurred in problem-solving, while classifying objects showed the smallest change across the research stages.

Cycle I Findings and Instructional Adjustments for Cycle II

At the end of Cycle I, the class mean reached 67.40, and seven students (41.18%) achieved the KKTP. Although the mean increased by 7.84 points compared with the pre-cycle, 10 students (58.82%) remained below the mastery threshold. Thirteen students improved their scores, while four students recorded no change. None of the seven students whose pre-cycle scores were at or below 41.67 achieved the KKTP in Cycle I. The indicator scores provided further information about the areas requiring attention. Indicator 5 reached 54.41%, while Indicator 6 remained at 30.88%. These results showed that selecting appropriate mathematical procedures and applying concepts to solve problems continued to be areas of difficulty at the end of the first cycle.

The Cycle I reflection informed adjustments to the instructional arrangements in Cycle II. During Cycle I, students had been organized into homogeneous groups based on their pre-cycle scores. For Cycle II, the groups were reorganized heterogeneously, and members were assigned specific roles: group leader, mission reader, recorder, and timekeeper/explorer. Guidance through the student worksheets (Lembar Kerja Peserta Didik, LKPD) was also strengthened, particularly for tasks requiring students to select appropriate operations and solve contextual problems. Cycle II addressed multiplication and division, following the addition and subtraction content in Cycle I. At the end of Cycle II, the class mean reached 81.62, all 17 students met the KKTP, and the minimum score increased to 75.00. The indicator scores for procedures and operations selection and problem-solving also reached 75.00% and 66.18%, respectively. These results document the changes in performance following the instructional adjustments, although the descriptive design does not isolate the contribution of each adjustment from the other changes between cycles.

A supplementary comparison based on students' pre-cycle performance showed different score trajectories between the lower-performing group of seven students and the remaining ten students. The lower-performing group had a mean of 36.90 in the pre-cycle, 51.79 in Cycle I, and 77.38 in Cycle II. The other ten students had corresponding means of 75.42, 78.33, and 84.58. From the pre-cycle to Cycle II, the lower-performing group gained 40.48 points, compared with 9.16 points for the other group. Both groups therefore recorded higher mean scores by the end of Cycle II, with a larger descriptive increase among students who had lower initial scores.

Summary of the Main Findings

The results show an overall increase in mathematical conceptual understanding during the two classroom action research cycles. The class mean rose from 59.56 in the pre-cycle to 81.62 in Cycle II, while classical mastery increased from 35.29% to 100%. All six conceptual understanding indicators recorded higher scores in Cycle II than in the pre-

cycle. Applying concepts to solve problems showed the largest overall increase, at 35.30 points, whereas classifying objects based on conceptual properties showed the smallest increase, at 5.88 points. Nevertheless, problem-solving remained the lowest-scoring indicator at the end of Cycle II. The descriptive results also show that the lower-performing group experienced a larger mean-score increase than the other students. These findings summarize the observed changes in student performance across the research stages without attributing the changes exclusively to any single instructional component.

Discussion

Changes in Students' Mathematical Conceptual Understanding

The findings indicate an improvement in Grade V students' mathematical conceptual understanding following the implementation of discovery learning assisted by M-ESCAPE for whole-number operations up to 100,000. The class mean increased from 59.56 in the pre-cycle to 67.40 in Cycle I and 81.62 in Cycle II. Classical mastery also increased from 35.29% to 41.18% and reached 100% in Cycle II. These results indicate positive changes in students' performance throughout the classroom action research process. The findings should be interpreted as improvements observed during the intervention rather than definitive evidence of the independent causal effect of M-ESCAPE, given the absence of a comparison group and the differences in mathematical content across assessment stages.

The improvement may be understood in relation to the structure of the learning activities. Before the intervention, students experienced difficulties selecting appropriate arithmetic operations and solving multistep word problems, while instruction relied primarily on teacher explanations, textbooks, and worksheets. M-ESCAPE introduced sequential mathematical missions through mission cards, supported students' reasoning through student worksheets (*Lembar Kerja Peserta Didik*, LKPD), and provided an opportunity to consolidate learning through the explorer certificate. This arrangement connected mathematical challenges with guided exploration and written problem-solving activities. The instructional value of M-ESCAPE therefore lies in the alignment between its physical materials, the learning process, and the intended conceptual objectives rather than in its adventure theme alone.

Recent research provides a relevant basis for examining game-based and discovery-oriented mathematics learning. A systematic review of non-digital games in primary mathematics education identified physical games as an important area for understanding how game-based activities are used to support mathematical learning (Russo et al., 2024). A primary-school mathematics case study also illustrated the importance of integrating digital gameplay with written mathematical work and problem-solving strategies (Deng et al., 2020). Classroom action research in Grade IV mathematics, using paired cards within the Make A Match model, likewise reported rising class means across two cycles, from 62.85 in the pre-cycle to 72.61 in Cycle I and 88.09 in Cycle II, although the outcome measured there was mathematical analytical thinking (Febiana et al., 2024). These findings provide a useful comparison for M-ESCAPE, in which students were required to work through mathematical missions and record their reasoning rather than simply complete game challenges. Differences in the media, participants, and research designs prevent direct equivalence between the findings of these studies and the present results.

The larger improvement observed in Cycle II may also be considered in relation to the instructional adjustments made after Cycle I. Cycle I used homogeneous groups based on

students' pre-cycle scores, whereas Cycle II introduced heterogeneous grouping, assigned group responsibilities, and more explicit guidance through the LKPD. These changes were intended to improve participation and organize students' engagement with the mathematical tasks. The subsequent improvement is consistent with the possibility that the revised learning arrangements supported students' work, although the contribution of each adjustment cannot be isolated from the available data. Research on discovery-oriented mathematics environments similarly emphasizes the importance of considering how learning activities are designed and organized rather than assuming that discovery alone guarantees learning (Weinhandl et al., 2025).

The interpretation of changes across cycles also requires consideration of the different mathematical content taught at each stage. The pre-cycle assessment covered the four arithmetic operations, Cycle I focused on addition and subtraction, and Cycle II addressed multiplication and division. The score increases therefore cannot be attributed exclusively to the revised grouping arrangements, students' familiarity with M-ESCAPE, or the learning model. The findings provide context-specific evidence that improvements in mathematical conceptual understanding occurred during the implementation of a structured physical medium integrated with guided discovery activities.

Differences in Development Across Conceptual Understanding Indicators

The indicator-level findings reveal that students' conceptual understanding developed unevenly. Applying concepts to solve problems showed the largest increase from the pre-cycle to Cycle II, rising from 30.88% to 66.18%, an increase of 35.30 percentage points. Classifying objects based on conceptual properties showed the smallest overall increase, from 75.00% to 80.88%, and remained unchanged between Cycle I and Cycle II. These differences demonstrate the importance of examining individual indicators alongside the overall class mean when evaluating changes in mathematical conceptual understanding.

The improvement in applying concepts to solve problems is particularly relevant because this indicator had the lowest initial score. Contextual mathematical problems can require students to identify relevant information, interpret relationships between quantities, select appropriate operations, organize solution steps, and check their answers. The mission-based structure of M-ESCAPE provided opportunities for students to engage with mathematical challenges through sequential tasks and guided worksheets. Such activities may have helped students approach problems in a more organized manner. Nevertheless, the final score for this indicator remained the lowest among the six indicators, suggesting that applying mathematical concepts to solve problems continued to be a substantial learning challenge.

Research on educational escape rooms provides a relevant comparison for the use of structured mathematical challenges. An escape-room approach has been examined as an alternative methodology for mathematics learning, demonstrating the relevance of designing mathematical activities around structured challenges and active participation (Fuentes-Cabrera et al., 2020). Research on non-digital games in primary mathematics education also provides a broader basis for considering physical game-based activities as part of mathematics instruction (Russo et al., 2024). These studies support the relevance of investigating challenge-based learning environments but do not establish that escape-room activities necessarily improve conceptual understanding of whole-number operations among elementary students. The present study contributes evidence from a

specific classroom context in which physical missions were aligned with the conceptual demands of arithmetic operations.

The difference between students' performance in expressing concepts and applying them to problems suggests that these dimensions may present different levels of difficulty. Students demonstrated comparatively stronger performance in restating concepts, while contextual problem-solving remained the weakest indicator at the end of Cycle II. This pattern is consistent with the possibility that expressing previously learned information may be less demanding than coordinating several steps to solve an unfamiliar or multistep problem. The present data do not establish the precise cognitive processes responsible for this difference. Further analysis of students' written explanations and solution strategies would be needed to determine whether the remaining difficulties involved interpreting word problems, selecting operations, organizing procedures, performing calculations, or coordinating these processes.

The limited improvement in classifying objects also deserves attention. This indicator began at a relatively high level and did not increase between Cycle I and Cycle II. The result indicates that the development of conceptual understanding was not uniform across all dimensions. Its limited change may be associated with differences in initial performance or task demands, but the available data do not establish a specific explanation. Instructional adjustments could therefore include asking students to justify their classifications, compare examples with non-examples, and apply conceptual properties to unfamiliar mathematical situations.

Theoretical Contributions and Instructional Implications

The principal contribution of this study lies in the integration of discovery learning with M-ESCAPE, a physical, adventure-themed medium organized around sequential mathematical missions. The findings do not establish a new general theory of mathematics learning. They document how structured missions, guided worksheets, group activities, and concluding tasks were incorporated into an elementary mathematics classroom to support the learning of whole-number operations up to 100,000. The contribution is consequently situated in the instructional design and its implementation in a specific educational context.

The use of physical materials also provides a relevant perspective on recent research into non-digital mathematics games. A systematic review of non-digital games in primary mathematics education highlights the relevance of investigating physical game formats within elementary mathematics learning (Russo et al., 2024). Research on tangible interfaces in primary mathematics has likewise examined how physical interaction can be incorporated into mathematics learning activities (Zito et al., 2021). M-ESCAPE extends this line of inquiry through a mission-based arrangement in which physical materials are combined with written mathematical tasks and guided exploration. The present study does not establish that this arrangement is superior to digital games, other learning media, or conventional instruction. The practical implications concern both the design of learning materials and the teacher's role in facilitating mathematical reasoning. M-ESCAPE uses a banner, mission cards, an LKPD, and an explorer certificate to serve complementary instructional functions.

Mission cards introduce mathematical challenges, the LKPD guides students in organizing information and solution steps, and the concluding activity provides an opportunity to consolidate learning. The effectiveness of this design in other classrooms

will depend on the alignment of the tasks with learning objectives, the clarity of instructions, and the opportunities students receive to explain their reasoning. The classroom action research process also highlights the importance of organizing collaborative learning deliberately. Heterogeneous grouping assigned group responsibilities, and more explicit worksheet guidance were introduced in Cycle II following reflection on Cycle I. Teachers using similar activities could consider assigning clear roles, monitoring the participation of individual students, and providing targeted guidance when students select operations or solve multistep problems. These practices represent instructional implications drawn from the classroom experience rather than independently tested effects of each component. The relatively low final performance on applying concepts to solve problems suggests that future instruction should emphasize contextual interpretation and multistep reasoning. Students could be asked to explain why a particular operation is appropriate, identify the information needed to solve a problem, compare alternative solution strategies, and verify whether their answers are consistent with the problem context. These activities would address the persistent difficulty identified in the indicator-level assessment and provide teachers with more detailed evidence of students' reasoning. The findings support the use of indicator-level assessment to guide instructional adjustments rather than relying solely on overall class averages.

Conclusion

This classroom action research examined the implementation of discovery learning assisted by M-ESCAPE, a physical adventure-themed learning medium, to support Grade V students' mathematical conceptual understanding of whole-number operations up to 100,000. The findings showed progressive improvements in students' assessment results across the research stages. The class mean increased from 59.56 in the pre-cycle to 67.40 in Cycle I and 81.62 in Cycle II, while the proportion of students achieving the minimum mastery criterion increased from 35.29% to 41.18% and ultimately reached 100%. Improvements varied across the six conceptual understanding indicators, with applying concepts to solve problems showing the largest overall increase of 35.30 percentage points. This indicator nevertheless remained the weakest at the end of Cycle II, highlighting the need for continued support in contextual and multistep problem-solving.

The findings suggest that integrating sequential mathematical missions, guided worksheets, collaborative activities, and structured reflection offer a practical approach to organizing discovery-oriented mathematics instruction. The instructional adjustments introduced in Cycle II, including heterogeneous grouping, assigned group roles, and more explicit worksheet guidance, formed part of the revised classroom practice. The study was limited by its small sample, single-classroom setting, absence of a comparison group, differences in mathematical content across stages, and use of one question per indicator. The results should therefore be interpreted as context-specific improvements rather than conclusive evidence of causal effectiveness. Future research should use comparable assessment tasks, larger samples, and comparative designs to examine the effectiveness and broader applicability of M-ESCAPE.

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