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Integrating the AMORA learning model and KOBIAS manipulative media for enhancing elementary students' mathematical conceptual understanding: A quasi-experimental study

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Abstract

Background: Elementary students' mathematical conceptual understanding remains a critical challenge because mathematics instruction often emphasizes procedural knowledge rather than meaningful concept construction. Although learner-centered pedagogies and manipulative media have individually demonstrated positive effects on mathematics learning, empirical evidence regarding their integrated implementation is still limited.
Aims: This study investigated the effect of integrating the AMORA learning model with KOBIAS (Kotak Bilangan Asli) manipulative media on elementary students' mathematical conceptual understanding.
Method: A quasi-experimental study employing a nonequivalent control group design was conducted with fifth-grade students selected through cluster random sampling. The experimental group received instruction using the integrated AMORA–KOBIAS approach, whereas the control group experienced conventional instruction. Data were collected through a validated mathematical conceptual understanding test and analyzed using descriptive statistics, normality and homogeneity tests, an independent-samples *t*-test, and normalized gain (N-gain) analysis.
Results: The experimental group significantly outperformed the control group ($p < .05$), achieving a higher mean post-test score (70.26 vs. 38.83). Moreover, the N-gain analysis indicated a moderate-to-high improvement in students' mathematical conceptual understanding following the intervention.
Conclusion: Integrating the AMORA learning model with KOBIAS manipulative media effectively enhances elementary students' mathematical conceptual understanding by promoting active concept construction through learner-centered instruction and concrete mathematical representations. This approach offers an effective instructional alternative for strengthening conceptual learning in elementary mathematics.

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INTRODUCTION

Mathematics is recognized as one of the most fundamental subjects in elementary education because it equips students with essential knowledge and cognitive competencies required for lifelong learning. Beyond developing computational skills, mathematics education aims to cultivate logical reasoning, critical thinking, creativity, communication, and problem-solving abilities that enable students to respond effectively to increasingly complex real-world situations (Nilimaa, 2023; Szabo et al., 2020; Torres-Peña et al., 2025). Among these competencies, mathematical conceptual understanding occupies a central position because it forms the foundation upon which students develop higher-order mathematical thinking. Students who possess strong conceptual

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understanding are able to explain mathematical ideas, establish meaningful relationships among concepts, represent concepts in multiple forms, and apply their knowledge flexibly across various contexts (Bolstad, 2020; Choppin et al., 2022; Hussein & Csíkos, 2023; Nilimaa, 2023). Conversely, students with weak conceptual understanding tend to rely on memorizing formulas and procedural algorithms without comprehending the underlying mathematical principles. This condition often results in fragmented knowledge structures that hinder students when they encounter unfamiliar mathematical situations or more advanced concepts. The inability to construct meaningful conceptual relationships also contributes to persistent misconceptions that negatively affect subsequent learning experiences. Consequently, strengthening mathematical conceptual understanding has become one of the primary goals of mathematics education at the elementary level. Achieving this objective requires instructional practices that encourage students to actively construct knowledge rather than merely receive information from teachers. Therefore, improving students' mathematical conceptual understanding continues to be an important challenge for researchers, educators, and curriculum developers seeking to improve the quality of elementary mathematics education.

Despite continuous efforts to improve mathematics instruction, many elementary classrooms continue to implement learning practices that emphasize procedural fluency and teacher-directed explanations more than conceptual exploration and active learning. In such learning environments, students frequently become passive recipients of information and have limited opportunities to investigate mathematical ideas through discussion, experimentation, and reflective thinking (Bognar et al., 2025; Nilimaa, 2023; Žakelj et al., 2024). As a result, mathematical concepts are often learned as isolated procedures rather than interconnected bodies of knowledge that can be meaningfully applied in different contexts. Another challenge lies in the abstract nature of mathematics, which frequently makes it difficult for elementary students to visualize and internalize mathematical relationships. Without appropriate instructional support, students may struggle to connect symbolic representations with concrete experiences that facilitate conceptual understanding. This challenge becomes even greater when learning activities rely predominantly on textbooks and verbal explanations while providing minimal opportunities for students to manipulate concrete mathematical objects. Meaningful learning is more likely to occur when students actively engage with mathematical concepts through exploration, collaboration, and reflection supported by appropriate instructional guidance (Koskinen & Pitkäniemi, 2022). Learning environments that promote autonomy, interaction, and constructive feedback also encourage students to develop confidence while constructing their own mathematical understanding. Consequently, mathematics instruction requires innovative pedagogical approaches that integrate learner-centered teaching with meaningful learning experiences capable of transforming abstract concepts into understandable representations. Such instructional innovation is expected to support deeper conceptual learning while simultaneously improving students' engagement and participation throughout the learning process.

Various instructional innovations have been introduced to improve mathematics learning, including inquiry-based learning, problem-based learning, contextual learning, realistic mathematics education, collaborative learning, and the use of manipulative learning media. These instructional approaches generally emphasize active student participation and have demonstrated positive contributions to mathematics learning outcomes by encouraging learners to construct knowledge through authentic experiences. Likewise, the use of concrete manipulative media has become increasingly important because it enables students to visualize abstract mathematical concepts and develop more meaningful conceptual representations. Physical manipulation of mathematical objects provides opportunities for students to observe relationships, test ideas, and refine their understanding through direct experience (Abrahamson et al., 2020; Byrne et al., 2023; Zou et al., 2025). Alongside these developments, humanistic approaches to education have gained increasing attention because they emphasize learner autonomy, meaningful interaction, empathy, and supportive classroom relationships as essential components of effective learning. One instructional model that reflects these principles is the AMORA learning model, which encourages students to learn through observation, guided exploration, reflection, and continuous teacher support within a learner-centered environment (Mir, 2025). The effectiveness of this instructional model has the potential to be strengthened through the integration of KOBIAS manipulative media, which provides concrete mathematical representations that facilitate conceptual construction while maintaining active student engagement. The integration of a humanistic learning model with manipulative media offers a comprehensive instructional approach that simultaneously addresses students' cognitive, affective, and experiential learning needs (Amini et al., 2025; Archambault et al., 2022; Herman et al., 2025; Meixia et al., 2025; Namboothiri et al., 2025). Such an integrated learning environment is expected to promote deeper mathematical conceptual understanding by combining meaningful pedagogical interactions with concrete mathematical experiences. Therefore, investigating the effectiveness of integrating the AMORA learning model and KOBIAS manipulative media represents an important step toward developing more effective instructional practices for elementary mathematics education.

Recent advances in mathematics education have demonstrated that student-centered instructional approaches effectively improve students' mathematical achievement, reasoning, engagement, and learning attitudes by promoting active participation and meaningful learning experiences (Emanet & Kezer, 2021; Thanheiser & Melhuish, 2023; Zahedi et al., 2023). Likewise, humanistic approaches have increasingly been recognized for fostering learner autonomy, empathy, reflective thinking, and supportive classroom environments that encourage meaningful mathematical learning (B. Bush et al., 2024; Furinghetti, 2020; Khadka et al., 2023). In parallel, numerous studies have confirmed that manipulative learning materials facilitate conceptual development by transforming abstract mathematical ideas into concrete representations, thereby improving students' mathematical learning and cognitive development (Byrne et al., 2023). Furthermore, various innovative instructional approaches, including project-based learning, realistic mathematics education, game-based learning, and technology-enhanced learning, have been shown to improve elementary mathematics learning outcomes (Debrenti, 2024; Fauzan et al., 2024; Lazi et al., 2021; Pellegrini et al., 2021). Nevertheless, existing studies have predominantly investigated these instructional models, pedagogical approaches, and manipulative media as separate interventions, with most research focusing on mathematics achievement, motivation, engagement, or reasoning rather than on mathematical conceptual understanding as a primary learning outcome. Consequently, empirical evidence regarding the integration of a humanistic learning model with manipulative learning media to systematically enhance elementary students' mathematical conceptual understanding remains limited. To address this gap, the present study integrates the AMORA learning model, which is grounded in Ki Hadjar Dewantara's humanistic educational philosophy, with KOBIAS manipulative media within a learner-centered instructional framework. By examining the effectiveness of this integrated approach through a quasi-experimental design, this study contributes new empirical evidence on how the synergy between humanistic pedagogy and concrete mathematical manipulatives can strengthen elementary students' mathematical conceptual understanding while extending the current body of knowledge in mathematics education.

This study aims to investigate the effect of integrating the AMORA learning model and KOBIAS manipulative media on enhancing elementary students' mathematical conceptual understanding. Specifically, the study examines whether students who learn through the integrated

AMORA–KOBIAS instructional approach achieve significantly higher levels of mathematical conceptual understanding than those receiving conventional mathematics instruction. The study also seeks to evaluate the effectiveness of combining a learner-centered instructional model with concrete manipulative media in facilitating meaningful mathematical learning. Furthermore, it explores the potential of this integrated approach to support students in constructing mathematical concepts through active engagement, exploration, and reflection. By focusing on mathematical conceptual understanding as the primary learning outcome, the study addresses an important aspect of mathematics learning that extends beyond procedural proficiency. The research is expected to provide empirical evidence regarding the instructional value of integrating humanistic learning principles with manipulative learning media in elementary mathematics classrooms. In addition, the findings are intended to enrich the theoretical understanding of learner-centered mathematics instruction by demonstrating how pedagogical integration can strengthen conceptual learning. From a practical perspective, the study offers an alternative instructional strategy that can assist teachers in designing more interactive, meaningful, and concept-oriented mathematics learning experiences. The results are also expected to serve as a reference for curriculum developers and educational practitioners in implementing innovative mathematics instruction at the elementary school level. Ultimately, this study contributes to the advancement of mathematics education research by proposing and empirically validating an integrated instructional framework that promotes students' mathematical conceptual understanding through the synergy of the AMORA learning model and KOBIAS manipulative media.

LITERATURE REVIEW

Mathematical conceptual understanding is widely recognized as a fundamental component of mathematics learning because it enables students to construct meaningful relationships among mathematical ideas rather than merely memorizing formulas and procedures. Conceptual understanding refers to students' ability to comprehend mathematical principles, explain the meaning of concepts, recognize relationships among representations, and apply mathematical knowledge appropriately in different situations (Hurrell, 2021; Hussein & Csíkos, 2023; Irshid et al., 2023; Manfreda Kolar & Hodnik, 2021; Ncube & Luneta, n.d.). Students who develop strong conceptual understanding are generally able to connect prior knowledge with new mathematical concepts, thereby facilitating meaningful and long-term learning. In contrast, students who rely primarily on procedural knowledge often experience difficulties when solving unfamiliar problems that require conceptual reasoning instead of routine algorithmic procedures. Conceptual understanding also serves as the foundation for developing higher-order mathematical competencies, including mathematical reasoning, problem solving, communication, and critical thinking. For this reason, contemporary mathematics curricula increasingly emphasize conceptual understanding as a central learning objective across all educational levels. The development of conceptual understanding requires learning experiences that encourage students to actively explore mathematical ideas, construct knowledge independently, and reflect on their own thinking processes. Meaningful mathematical learning therefore involves more than obtaining correct answers, as students are expected to explain why mathematical procedures work and how different concepts are interconnected. Such learning experiences enable students to develop flexible mathematical thinking that can be transferred to new contexts and authentic problem situations. Consequently, strengthening students' mathematical conceptual understanding has become one of the primary priorities in mathematics education research and instructional innovation.

Student-centered learning has become one of the dominant paradigms in contemporary mathematics education because it positions learners as active participants in constructing mathematical knowledge through exploration, discussion, and reflection rather than passive recipients of information. This instructional perspective is strongly influenced by constructivist learning theory, which argues that knowledge is actively constructed through interaction between learners and their learning environment. Within student-centered classrooms, teachers function primarily as facilitators who guide students in investigating mathematical ideas, encouraging inquiry, and supporting conceptual development (Drobnic Vidic, 2023; Machaba & Mangwiro, 2026; Stein et al., 2022). Such learning environments provide students with greater opportunities to express their reasoning, collaborate with peers, and evaluate alternative mathematical strategies during problem-solving activities. In addition to constructivist perspectives, humanistic learning theory emphasizes the importance of respecting learners' individuality, emotional well-being, autonomy, and intrinsic motivation throughout the learning process (Amini et al., 2025; Zahorodnia et al., 2026). Humanistic mathematics education encourages teachers to create supportive classroom environments in which students feel psychologically safe to express ideas, make mistakes, and develop confidence while learning mathematics. These learning principles are consistent with educational philosophies that promote meaningful learning through guidance, empathy, collaboration, and learner empowerment rather than authoritarian instruction. The integration of student-centered and humanistic learning principles has been shown to improve students' learning engagement, mathematical confidence, and conceptual understanding by encouraging active participation throughout classroom activities (Li, 2025). Furthermore, learning environments that support autonomy and reflective thinking contribute to deeper conceptual internalization because students are encouraged to examine and reconstruct their own mathematical understanding. Therefore, student-centered humanistic instruction provides an important theoretical foundation for designing mathematics learning experiences that facilitate meaningful conceptual development.

The AMORA learning model represents a learner-centered instructional approach that is grounded in Ki Hadjar Dewantara's philosophy of education, particularly the principles embodied in the Among System. This instructional model emphasizes guidance, care, learner autonomy, and meaningful interaction as essential components of effective teaching and learning. The learning process is organized through four interconnected stages, namely *Amati*, *Momong*, *Ngrasake*, and *Among*, each of which supports students in constructing mathematical knowledge through progressive learning experiences. During the *Amati* stage, students observe contextual situations and activate prior knowledge that serves as the foundation for learning new mathematical concepts. The *Momong* stage encourages learners to explore mathematical ideas independently while receiving appropriate guidance from teachers and peers throughout the learning process. Subsequently, the *Ngrasake* stage provides opportunities for students to reflect on their learning experiences, express mathematical ideas, and strengthen conceptual understanding through meaningful interaction. Finally, the *Among* stage reinforces students' conceptual understanding by encouraging collaborative discussion, teacher facilitation, and continuous reflection on mathematical reasoning. Previous implementations of the AMORA learning model have demonstrated positive effects on students' learning independence, mathematical thinking habits, classroom participation, and academic achievement (Capone, 2022; Egara & Mosimege, 2024; Liu et al., 2024). Nevertheless, empirical investigations examining its effectiveness in improving mathematical conceptual understanding remain relatively limited, particularly when the model is integrated with concrete manipulative learning media. Consequently, further investigation is necessary to determine how the integration of the AMORA learning model with manipulative instructional media can optimize students' mathematical conceptual understanding in elementary mathematics education.

Manipulative learning media have become an essential component of elementary mathematics education because they provide concrete representations that help students understand abstract mathematical concepts. Elementary school students generally remain in the transition from concrete operational to formal operational thinking, making physical interaction with learning materials particularly important for meaningful conceptual development. Through manipulative media, students are able to observe, compare, classify, and represent mathematical relationships that might otherwise remain difficult to comprehend through symbolic notation alone. KOBIAS (Kotak Bilangan Asli) is a manipulative learning medium specifically designed to facilitate students' understanding of number concepts and arithmetic operations through direct manipulation and interactive learning activities. The design of KOBIAS encourages learners to actively construct mathematical relationships by arranging, combining, and interpreting numerical representations while solving mathematical problems. Such learning experiences reduce students' dependence on rote memorization because mathematical ideas are developed through concrete exploration before being generalized into abstract concepts. The use of manipulative media has also been associated with increased learning motivation, classroom participation, and mathematical confidence because students become directly involved in the learning process. Furthermore, embodied cognition theory suggests that cognitive development is strengthened when learners physically interact with instructional materials, allowing sensory and motor experiences to reinforce conceptual understanding (Abrahamson et al., 2020; Chang & Aberash, 2026; Faella et al., 2025; Kosmas & Zaphiris, 2023; Zou et al., 2025). Consequently, manipulative learning media such as KOBIAS are expected to support the development of deeper conceptual understanding by integrating visual, tactile, and cognitive experiences within mathematics learning. Therefore, KOBIAS provides an appropriate instructional medium for facilitating elementary students' mathematical conceptual understanding while supporting meaningful and learner-centered mathematics instruction.

Recent developments in mathematics education emphasize that effective instructional innovation should integrate appropriate pedagogical approaches with learning media rather than implementing these components independently. The effectiveness of learner-centered instruction is likely to increase when students are provided with concrete learning resources that facilitate active exploration and conceptual construction throughout the learning process. The integration of the AMORA learning model and KOBIAS manipulative media represents such an instructional framework because both components complement one another in supporting meaningful mathematics learning. While the AMORA learning model provides structured pedagogical stages that encourage observation, guided inquiry, reflection, and collaborative learning, KOBIAS offers concrete mathematical representations that enable students to visualize and manipulate abstract concepts directly. This instructional synergy creates learning experiences that simultaneously address students' cognitive, affective, and psychomotor domains, thereby promoting more comprehensive conceptual development (Kwan et al., 2025; Retno et al., 2025). Students are encouraged not only to understand mathematical procedures but also to explain concepts, justify reasoning, communicate mathematical ideas, and apply conceptual knowledge to solve unfamiliar problems. Such characteristics are consistent with contemporary mathematics education perspectives that advocate meaningful, inquiry-oriented, and student-centered learning environments capable of developing higher-order mathematical competencies. Despite the growing body of research on learner-centered instruction and manipulative learning media, empirical investigations examining their integrated implementation for strengthening mathematical conceptual understanding remain relatively limited, particularly at the elementary school level. Consequently, investigating the effectiveness of integrating the AMORA learning model and KOBIAS manipulative media provides an important contribution to both instructional practice and mathematics education research by addressing this gap in the literature. This theoretical foundation supports the hypothesis that the integrated AMORA–KOBIAS instructional approach has substantial potential to enhance elementary students' mathematical conceptual understanding more effectively than conventional mathematics instruction.

METHOD

Research Design

This study employed a quantitative approach using a quasi-experimental research design with a nonequivalent control group design. This design was selected because the researchers were unable to randomly assign individual students to the experimental and control groups due to existing classroom organization within the participating schools. Instead, intact classes were maintained to preserve the natural learning environment while allowing comparisons between different instructional approaches. The study involved two groups consisting of an experimental group that received mathematics instruction through the integration of the AMORA learning model and KOBIAS manipulative media and a control group that received conventional teacher-centered mathematics instruction. Both groups were administered identical pre-tests before the instructional intervention and post-tests after the intervention to measure changes in students' mathematical conceptual understanding. The independent variable in this study was the integrated AMORA–KOBIAS instructional approach, whereas the dependent variable was students' mathematical conceptual understanding. The nonequivalent control group design enabled the researchers to examine the effectiveness of the instructional intervention by comparing learning outcomes between the two groups while controlling for their initial abilities through pre-test measurement. The research design also minimized disruption to regular classroom instruction because all learning activities were conducted within the existing school schedule. Overall, the selected research design was considered appropriate for evaluating the causal effect of integrating the AMORA learning model and KOBIAS manipulative media on students' mathematical conceptual understanding under authentic educational conditions. The research design is illustrated in Table 1.

Table 1. Nonequivalent Control Group Design

Group	Pre-test	Treatment	Post-test
Experimental	O_1	X	O_2
Control	O_3	–	O_4

Source: Adapted from Sugiyono (Ningsih & Wulandari, 2022).

Where:
O_1 = Pre-test of the experimental group
O_2 = Post-test of the experimental group
O_3 = Pre-test of the control group
O_4 = Post-test of the control group
X = Mathematics instruction using the integrated AMORA learning model and KOBIAS manipulative media.

Participants

The study was conducted in Cluster IV elementary schools located in Banyuresmi District, Indonesia. The target population consisted of all fifth-grade students enrolled in eight public elementary schools within the cluster. Prior to sample selection, an equivalence test was conducted to identify schools with relatively similar academic characteristics and learning conditions to ensure comparability between the research groups. Following the equivalence assessment, cluster random sampling was employed because the participants were organized into naturally existing classroom groups. Two stages of lottery-based randomization were subsequently conducted to determine the participating schools and assign the experimental and control classes. The final sample consisted of one experimental class and one control class, with each class comprising twenty-three students, resulting in a total sample of forty-six participants. Students in the experimental class participated in mathematics learning through the integration of the AMORA learning model and KOBIAS manipulative media, whereas students in the control class received conventional mathematics instruction delivered through teacher-centered approaches. Both groups studied the same mathematical topic during the same academic semester and were taught according to the same curriculum to maintain instructional consistency. Participation in the study was conducted with permission from the participating schools, and all data collected during the research process were used exclusively for academic purposes while maintaining the confidentiality of participants' identities. The instructional material focused on mixed arithmetic operations involving natural numbers, one of the core competencies in the Grade V elementary mathematics curriculum. This topic requires students to understand and apply the hierarchy of arithmetic operations while solving numerical expressions and contextual mathematical problems. The selected topic was considered appropriate because it requires students to demonstrate conceptual understanding rather than merely applying memorized computational procedures.

Instruments and Data Collection

The primary research instrument was a mathematical conceptual understanding test designed to measure students' mastery of fundamental mathematical concepts after the instructional intervention. The test was developed according to the conceptual understanding indicators outlined in the elementary mathematics curriculum and consisted of essay items requiring students to demonstrate conceptual reasoning rather than procedural computation. Specifically, the instrument assessed students' ability to restate mathematical concepts using their own words, classify mathematical objects according to specific properties, distinguish examples from non-examples of mathematical concepts, represent concepts using multiple mathematical representations, and apply mathematical concepts and procedures to solve contextual problems. Prior to implementation, the instrument underwent expert judgment to evaluate its content validity, language appropriateness, and alignment with the learning objectives. Subsequently, an empirical pilot test was conducted to examine the validity and reliability of the instrument before its administration in the main study. The validation results indicated that all items satisfied the required validity criteria and were therefore considered appropriate for measuring students' mathematical conceptual understanding. Data collection was conducted through three consecutive stages consisting of pre-test administration, instructional intervention, and post-test administration. The pre-test was administered before the learning intervention to identify students' initial conceptual understanding, whereas the post-test was conducted immediately after the completion of the instructional treatment. Both assessments were administered under standardized classroom conditions to ensure consistency in data collection across the experimental and control groups.

Data Analysis

The collected data were analyzed using both descriptive and inferential statistical techniques with the assistance of IBM SPSS Statistics version 29. Descriptive statistics were first employed to summarize students' pre-test and post-test performance by calculating the mean, standard deviation, minimum score, and maximum score for each research group. Prior to hypothesis testing, prerequisite analyses were conducted to ensure that the data satisfied the assumptions required for parametric statistical procedures. The normality of the data distribution was examined using the

Kolmogorov–Smirnov test, whereas the homogeneity of variances between the two groups was evaluated using Levene's test. After these assumptions were satisfied, an independent-samples *t*-test was performed to determine whether statistically significant differences existed between the post-test scores of the experimental and control groups. To evaluate the magnitude of students' learning improvement, normalized gain (N-gain) analysis was calculated by comparing students' pre-test and post-test scores. The resulting N-gain values were interpreted according to established classification criteria to determine the effectiveness of the instructional intervention in improving students' mathematical conceptual understanding. Statistical significance for all inferential analyses was determined at the 0.05 probability level. The combination of descriptive statistics, prerequisite testing, hypothesis testing, and learning gain analysis provided a comprehensive evaluation of the effectiveness of integrating the AMORA learning model and KOBIAS manipulative media in elementary mathematics instruction.

Research Procedure

The research procedure consisted of five sequential stages to ensure systematic implementation and methodological consistency throughout the study. The first stage involved conducting a comprehensive literature review, identifying the research problem, developing the conceptual framework, preparing instructional materials, designing the KOBIAS manipulative media, and constructing the mathematical conceptual understanding test. The second stage focused on validating the research instrument through expert evaluation, conducting empirical testing, revising the instrument based on the validation results, and coordinating the research implementation with the participating elementary schools. During the third stage, a pre-test was administered to both the experimental and control groups to determine students' initial levels of mathematical conceptual understanding before the instructional intervention. The fourth stage consisted of implementing the learning intervention, in which the experimental group received mathematics instruction through the integration of the AMORA learning model and KOBIAS manipulative media, while the control group participated in conventional teacher-centered mathematics instruction covering the same learning material. Throughout the intervention period, both groups studied identical mathematical content and received equivalent instructional time to maintain treatment comparability. Following the completion of the instructional intervention, all participants completed the post-test under standardized classroom conditions to measure changes in their mathematical conceptual understanding. The fifth stage involved organizing the collected data, performing statistical analyses using IBM SPSS Statistics version 29, interpreting the research findings, and evaluating the effectiveness of the integrated instructional approach. Finally, the findings were synthesized to formulate conclusions regarding the contribution of integrating the AMORA learning model and KOBIAS manipulative media to enhancing elementary students' mathematical conceptual understanding. This systematic research procedure ensured methodological rigor, strengthened the credibility of the findings, and enhanced the reproducibility of the study for future mathematics education research.

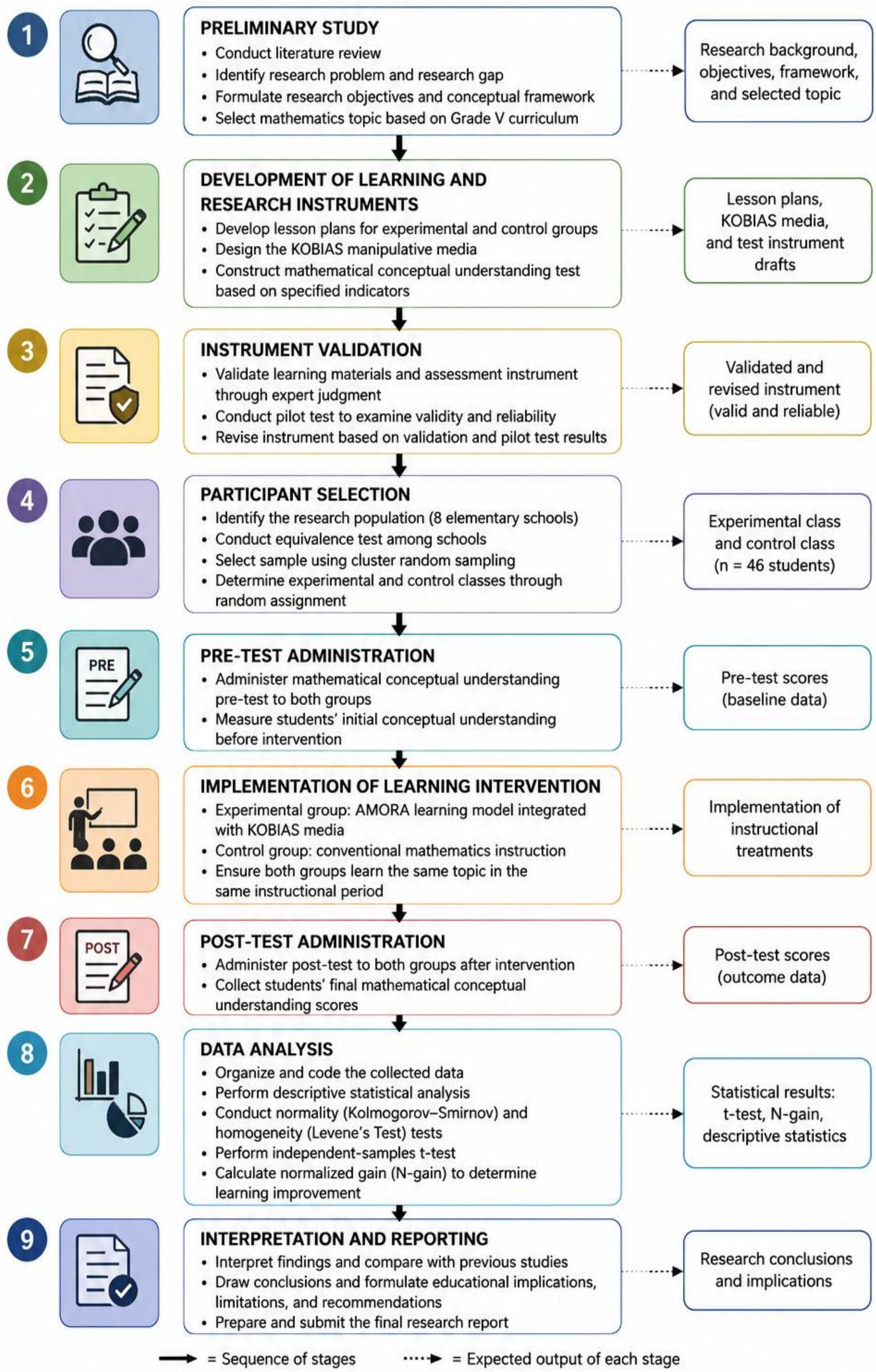

Figure 1. Research Method Flow

RESULTS AND DISCUSSION

Results

Instrument Validity

Prior to the implementation of the study, the mathematical conceptual understanding test was subjected to content validation and empirical testing. The validation results indicated that all test items met the required validity criteria, with item-total correlation coefficients exceeding 0.40 at the 5% significance level. Therefore, all items were considered appropriate for measuring students' mathematical conceptual understanding.

Normality Test

The normality of the data was examined using the Kolmogorov–Smirnov test. The results revealed that both pre-test and post-test scores in the experimental group were normally distributed, with significance values of 0.451 and 0.887, respectively.

Table 2. SPSS Output for Normality Test: Experimental Class

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	kelas	Statistic	df	Sig.	Statistic	df	Sig.
hasil	pretest A (eksperimen)	,078	23	,200*	,959	23	,451
	posttest A (eksperimen)	,089	23	,200*	,979	23	,887

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Source: Data processed by the researcher (2025)

Similarly, the control group demonstrated normal data distribution, with significance values of 0.459 for the pre-test and 0.940 for the post-test. Since all significance values were greater than 0.05, the assumption of normality was satisfied.

Table 3. SPSS Output for Normality Test: Control Class

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	kelas	Statistic	df	Sig.	Statistic	df	Sig.
hasil	pretest A (kontrol)	,094	23	,200*	,960	23	,459
	posttest A (kontrol)	,108	23	,200*	,982	23	,940

*. This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Source: Data processed by the researcher (2025)

Homogeneity Test

The homogeneity of variance between the experimental and control groups was assessed using Levene's Test. The analysis produced a significance value of 0.087, which exceeded the significance level of 0.05. This finding indicates that the variances of the two groups were homogeneous, allowing further analysis using parametric statistical procedures.

Table 4. Output SPSS Uji Homogen

Test of Homogeneity of Variance

		Levene Statistic	df1	df2	Sig.
nilai	Based on Mean	3,056	1	44	,087
	Based on Median	2,951	1	44	,093
	Based on Median and with adjusted df	2,951	1	40,862	,093
	Based on trimmed mean	3,060	1	44	,087

Source: Data processed by the researcher (2025)

Independent Samples t-Test

An Independent Samples t-test was conducted to examine differences in mathematical conceptual understanding between students who learned through the AMORA learning model assisted by KOBIAS media and those who received conventional instruction.

Table 5. Output SPSS Uji-T Post-Test

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
nilai	Equal variances assumed	3,056	,087	-27,783	44	<,001	<,001	-31,435	1,131	-33,715	-29,155
	Equal variances not assumed			-27,783	40,131	<,001	<,001	-31,435	1,131	-33,721	-29,148

Source: Data processed by the researcher (2025)

The results indicated a statistically significant difference between the two groups. The significance value obtained from the two-tailed test was less than 0.001, which was substantially lower than the established significance level of 0.05. Therefore, the null hypothesis was rejected, indicating that students who participated in learning activities using the AMORA learning model assisted by KOBIAS media achieved significantly better mathematical conceptual understanding than those who experienced conventional instruction.

Comparison of Learning Outcomes

To compare students' mathematical conceptual understanding after the implementation of the instructional intervention, descriptive statistics were analyzed. The comparison of the post-test scores between the experimental and control groups is presented in Table 6.

Table 6. Average Score

Group Statistics

	kelas	N	Mean	Std. Deviation	Std. Error Mean
nilai	posttest kelas kontrol	23	38,83	3,186	,664
	posttest kelas eksperimen	23	70,26	4,392	,916

Source: Data processed by the researcher (2025)

As shown in Table 6, the experimental group consisted of 23 students with a mean post-test score of 70.26 (SD = 4.392), whereas the control group also consisted of 23 students but obtained a lower mean score of 38.83 (SD = 3.186). The higher mean score achieved by the experimental group indicates that students who learned through the AMORA learning model assisted by KOBIAS media demonstrated better mathematical conceptual understanding than those who received conventional mathematics instruction. Furthermore, the relatively small standard deviations in both groups indicate that students' post-test scores were fairly consistent within each group. These descriptive findings provide preliminary evidence that the AMORA learning model assisted by KOBIAS media contributed positively to students' mathematical conceptual understanding. However, to determine whether the observed difference between the two groups was statistically significant, an Independent Samples t-test was conducted, as presented in the following section.

Discussion

The findings of this study demonstrate that integrating the AMORA learning model and KOBIAS manipulative media significantly improves elementary students' mathematical conceptual understanding compared with conventional mathematics instruction. The significantly higher post-test scores achieved by the experimental group indicate that the integrated instructional approach successfully facilitated students in constructing mathematical concepts through meaningful learning experiences rather than relying solely on procedural memorization. This finding suggests that conceptual understanding develops more effectively when students are actively engaged in exploring mathematical ideas and connecting new knowledge with their prior experiences. Such learning conditions enable students to organize mathematical knowledge into coherent conceptual structures that can be applied flexibly across different mathematical contexts. The improvement observed in this study is consistent with the constructivist perspective, which argues that conceptual knowledge is actively constructed through interaction, exploration, and reflection rather than transmitted directly from teachers to students. The present findings are also consistent with previous studies reporting that student-centered mathematics instruction contributes more effectively to conceptual learning than teacher-centered instructional approaches because it encourages students to participate actively in the learning process (Emanet & Kezer, 2021; Zvoch et al., 2021). Similarly, recent meta-analytic evidence has shown that learner-centered instructional strategies positively influence mathematics achievement, learning engagement, and students' attitudes toward mathematics by providing opportunities for active knowledge construction (Rizakhojayeva et al., 2025; Ting et al., 2023). Unlike many previous studies that primarily examined mathematics achievement or procedural performance, the present study specifically demonstrates improvements in mathematical conceptual understanding as the principal learning outcome. This distinction is important because conceptual understanding serves as the foundation for developing higher-order mathematical competencies, including reasoning, problem solving, and mathematical communication. Therefore, the findings provide additional empirical evidence that integrating learner-centered pedagogy with meaningful mathematical experiences represents an effective instructional strategy for strengthening conceptual learning in elementary mathematics education.

One important factor contributing to the effectiveness of the instructional intervention lies in the pedagogical characteristics of the AMORA learning model, which emphasizes learner autonomy, meaningful interaction, guided exploration, and reflective learning throughout the instructional process. The *Amati* stage encourages students to activate prior knowledge and relate previously acquired concepts to new mathematical ideas, thereby facilitating meaningful conceptual construction. During the *Momong* stage, students actively investigate mathematical relationships, formulate explanations, and test their own understanding through teacher-guided inquiry and collaborative discussion. These learning experiences promote cognitive engagement because students are encouraged to construct mathematical knowledge independently instead of passively receiving explanations from the teacher. The *Ngrasake* stage further strengthens conceptual understanding by providing opportunities for reflection, self-expression, and continuous feedback that enable students to evaluate and reorganize their mathematical thinking. Subsequently, the *Among* stage reinforces conceptual learning through collaborative interaction and teacher facilitation, allowing misconceptions to be clarified while encouraging students to justify their mathematical reasoning. These instructional characteristics closely reflect the principles of humanistic learning, which emphasize learner empowerment, psychological safety, and meaningful educational experiences. The findings therefore support previous research reporting that student-centered and humanistic instructional approaches improve students' conceptual understanding, learning motivation, and classroom participation by creating environments that encourage active engagement and independent knowledge construction (Ahmed & Mikail, 2023; Amini et al., 2025; Bhardwaj et al., 2022; Li, 2025). Nevertheless, whereas earlier studies generally examined student-centered learning or humanistic pedagogy independently, the present study demonstrates that combining these principles within the AMORA learning model produces meaningful improvements in students' mathematical conceptual understanding. Consequently, the findings extend previous literature by providing empirical evidence that humanistic mathematics instruction can effectively strengthen conceptual learning when implemented through a structured learner-centered instructional framework.

Another important finding of this study concerns the contribution of KOBIAS manipulative media to facilitating students' mathematical conceptual understanding through concrete learning experiences. Mathematics is inherently abstract, and many elementary students experience difficulties because symbolic mathematical representations are often introduced before learners have developed adequate conceptual foundations. KOBIAS manipulative media addresses this challenge by allowing students to physically manipulate numbers and mathematical operations while exploring relationships among mathematical concepts. Direct interaction with concrete mathematical representations enables students to visualize abstract ideas more clearly and reduces cognitive difficulties associated with symbolic reasoning. These findings are consistent with research demonstrating that manipulative learning materials improve conceptual understanding because they bridge the gap between concrete experiences and abstract mathematical representations (Ahmad & Siller, 2024; Ebner et al., 2025; Siller & Ahmad, 2024). Previous studies have also shown that concrete manipulatives increase students' motivation, classroom participation, and mathematical achievement by encouraging active exploration and collaborative problem solving. In addition, embodied learning perspectives suggest that physical interaction with learning materials supports conceptual development because cognitive processing is strengthened through sensory and motor experiences. Unlike conventional manipulative media that primarily function as visual aids, KOBIAS integrates physical manipulation with structured learner-centered activities embedded within the AMORA instructional stages, thereby creating a more comprehensive learning experience. The combination of active exploration, collaborative discussion, and concrete mathematical representation appears to have facilitated deeper conceptual internalization than either instructional component could achieve independently. Therefore, the present findings provide new empirical support for integrating manipulative learning media with learner-centered instructional models as an effective strategy for improving elementary students' mathematical conceptual understanding.

The effectiveness of the integrated AMORA–KOBIAS instructional approach can also be explained through the complementary interaction between learner-centered pedagogy and concrete manipulative learning media. While the AMORA learning model provides a structured pedagogical framework that encourages observation, guided inquiry, reflection, and collaborative learning, KOBIAS manipulative media translates these pedagogical principles into tangible mathematical experiences that facilitate conceptual construction. This complementary relationship enables students not only to understand mathematical procedures but also to develop meaningful conceptual representations through direct interaction with mathematical objects. Unlike instructional approaches that emphasize either pedagogical innovation or learning media independently, the present study demonstrates that integrating both components creates a richer learning environment capable of supporting cognitive, affective, and behavioral dimensions of mathematics learning simultaneously. Such integration promotes active engagement because students continuously observe, manipulate, discuss, evaluate, and refine their mathematical understanding throughout the learning process. Previous studies investigating instructional models or manipulative media separately have generally reported improvements in mathematics achievement, learning motivation, or classroom engagement; however, relatively few studies have examined the pedagogical synergy generated by combining these instructional components within a single learning framework. The present findings therefore extend the existing literature by demonstrating that the simultaneous integration of a humanistic instructional model and manipulative learning media produces meaningful improvements in mathematical conceptual understanding beyond those commonly reported for isolated instructional interventions. From a theoretical perspective, these findings support the view that conceptual learning is optimized when cognitive processes are reinforced through meaningful social interaction, reflective thinking, and concrete experiential learning (Cheng et al., 2025; Javahery & Bavandi, 2026; Kee & Zhang, 2022). This integrated instructional approach also reflects contemporary perspectives in mathematics education that advocate the combination of effective pedagogy, appropriate instructional resources, and active student participation as essential elements of high-quality mathematics instruction. Consequently, the AMORA–KOBIAS integration represents an innovative instructional framework that contributes to both instructional practice and the theoretical development of learner-centered mathematics education.

The findings of this study have important implications for the advancement of elementary mathematics education from both theoretical and practical perspectives. Theoretically, this study extends existing knowledge by demonstrating that mathematical conceptual understanding can be strengthened through the integration of humanistic learning principles with concrete manipulative learning experiences rather than relying on either instructional approach independently. The study also reinforces constructivist and humanistic learning theories by showing that students develop deeper conceptual understanding when they actively construct knowledge through exploration, collaboration, reflection, and meaningful interaction with instructional materials. From a practical perspective, the findings provide evidence that mathematics teachers should design learning environments that encourage students to participate actively while utilizing manipulative media capable of representing abstract mathematical concepts in concrete forms (Abrahamson et al., 2020; Ochogboju & Díez-Palomar, 2025). The integration of the AMORA learning model and KOBIAS manipulative media offers teachers a systematic instructional framework that simultaneously promotes conceptual understanding, learner autonomy, collaborative learning, and reflective thinking. These characteristics are particularly important for elementary mathematics instruction because conceptual understanding developed during the early years of schooling serves as the foundation for subsequent mathematical learning. Furthermore, curriculum developers may consider incorporating instructional approaches that combine learner-centered pedagogy with manipulative learning media to improve the quality of mathematics teaching and learning in elementary schools. The findings also encourage educational policymakers to provide professional development programs that strengthen teachers' competencies in implementing innovative instructional models supported by appropriate learning media. Although the present study focused on mixed arithmetic operations involving natural numbers, the integrated instructional framework has considerable potential to be adapted for other mathematical topics requiring conceptual understanding, including fractions, geometry, algebraic thinking, and measurement. Overall, this study contributes meaningful empirical evidence that supports the development of more engaging, meaningful, and concept-oriented mathematics instruction while providing a foundation for future research examining the effectiveness of integrated learner-centered instructional approaches in diverse educational contexts.

Implications

The findings of this study have important theoretical, pedagogical, and practical implications for the advancement of elementary mathematics education. From a theoretical perspective, the study extends the current body of knowledge by demonstrating that integrating a humanistic learning model with manipulative learning media provides a more comprehensive instructional framework for developing students' mathematical conceptual understanding than implementing either approach independently. The results also reinforce constructivist and humanistic learning theories by confirming that meaningful conceptual understanding develops through active exploration, collaborative interaction, reflective thinking, and concrete learning experiences. From a pedagogical perspective, the study provides evidence that mathematics teachers should move beyond procedural instruction and adopt learner-centered instructional strategies that actively engage students in constructing mathematical concepts. The integration of the AMORA learning model and KOBIAS manipulative media offers a structured learning environment that simultaneously promotes conceptual understanding, learner autonomy, mathematical communication, and collaborative problem solving. The instructional framework proposed in this study also demonstrates that concrete mathematical representations can effectively bridge the gap between abstract mathematical concepts and students' prior experiences, thereby reducing misconceptions and facilitating deeper conceptual learning. These findings suggest that manipulative learning media should not merely function as supplementary teaching aids but should be systematically integrated into instructional models that encourage inquiry, reflection, and meaningful knowledge construction. For curriculum developers, the study provides empirical evidence supporting the incorporation of integrated learner-centered instructional approaches into elementary mathematics curricula to strengthen students' conceptual competencies from the early years of schooling. The findings further indicate that teacher professional development programs should emphasize not only innovative instructional models but also effective strategies for integrating pedagogical approaches with appropriate learning media to maximize students' learning outcomes. From an institutional perspective, schools may utilize the integrated AMORA–KOBIAS framework as an alternative instructional innovation to create more interactive, engaging, and concept-oriented mathematics classrooms. The integrated instructional approach also has the potential to be adapted to other mathematical topics that require strong conceptual understanding, including fractions, geometry, measurement, and algebraic reasoning. Ultimately, this study provides empirical support for the development of more meaningful, student-centered, and concept-oriented mathematics instruction while contributing a practical instructional framework that can guide future innovations in elementary mathematics education.

Limitations and Suggestions for Future Research

This study has several limitations that should be considered when interpreting its findings and planning future research. First, the study was conducted using a quasi-experimental design involving only two intact classes from elementary schools within a single school cluster, which may limit the generalizability of the findings to broader educational contexts with different student characteristics and instructional environments. Second, the instructional intervention focused exclusively on mixed arithmetic operations involving natural numbers; therefore, the effectiveness of the integrated AMORA learning model and KOBIAS manipulative media for other mathematical domains remains uncertain. Third, the duration of the intervention was relatively short and assessed only students' immediate learning outcomes, making it difficult to determine the long-term retention and sustainability of improvements in mathematical conceptual understanding. Fourth, the study relied primarily on quantitative assessment through a mathematical conceptual understanding test and did not explore students' learning experiences, reasoning processes, or classroom interactions using qualitative methods. Fifth, although the study demonstrated statistically significant improvements in conceptual understanding, it did not examine the influence of individual learner characteristics, such as prior mathematical ability, learning motivation, self-efficacy, or cognitive style, which may moderate the effectiveness of the instructional approach. Future research is therefore recommended to replicate this study using larger and more diverse samples from different geographical regions and educational settings to improve the external validity of the findings. Further investigations should also examine the effectiveness of the integrated AMORA–KOBIAS approach across various mathematical topics, including fractions, geometry, measurement, algebraic thinking, and data representation, to determine its broader applicability within elementary mathematics education. Longitudinal studies are needed to evaluate the long-term effects of the instructional intervention on students' conceptual retention, mathematical reasoning, and problem-solving abilities. Moreover, future studies should adopt mixed-methods or qualitative approaches to provide deeper insights into students' conceptual development, learning behaviors, and classroom interactions throughout the implementation of the instructional model. Additional research is also encouraged to investigate the mediating or moderating roles of variables such as learning motivation, mathematical self-efficacy, engagement, digital literacy, and teacher instructional competence in influencing the effectiveness of the integrated instructional framework. Finally, comparative studies involving different learner-centered instructional models, technology-enhanced manipulative media, or digital interactive learning environments would further enrich the evidence base and contribute to the continued refinement of innovative instructional strategies for strengthening elementary students' mathematical conceptual understanding.

CONCLUSION

This study investigated the effectiveness of integrating the AMORA learning model and KOBIAS (Kotak Bilangan Asli) manipulative media in enhancing elementary school students' mathematical conceptual understanding through a quasi-experimental research design. The findings demonstrated that students who participated in the integrated AMORA–KOBIAS instructional approach achieved significantly higher mathematical conceptual understanding than those who received conventional mathematics instruction, confirming the superiority of learner-centered and manipulative-based learning over traditional teaching practices. The statistical analyses further revealed a significant difference between the experimental and control groups, while the normalized gain analysis indicated a moderate-to-high level of improvement, providing strong evidence of the effectiveness of the instructional intervention. These findings suggest that meaningful conceptual understanding is more effectively developed when students actively construct mathematical knowledge through observation, guided exploration, collaborative interaction, reflection, and continuous teacher support. The effectiveness of the intervention can be attributed to the complementary integration of the AMORA learning model, which emphasizes humanistic and learner-centered learning principles, with KOBIAS manipulative media, which transforms abstract mathematical concepts into concrete and meaningful learning experiences. This instructional synergy enabled students to visualize mathematical relationships, strengthen conceptual representations, and apply mathematical ideas more confidently in problem-solving situations. The findings also demonstrate that combining pedagogical innovation with concrete instructional media provides richer learning experiences than implementing either component independently. From a theoretical perspective, this study contributes to mathematics education by extending the understanding of how humanistic learning principles and manipulative media can be integrated within a unified instructional framework to strengthen students' mathematical conceptual understanding. From a practical perspective, the integrated AMORA–KOBIAS approach offers mathematics teachers an effective alternative for designing engaging, interactive, and concept-oriented classroom instruction that promotes active student participation and meaningful learning. The results further indicate that integrating learner-centered pedagogy with manipulative learning media has considerable potential to improve the quality of elementary mathematics instruction while supporting the development of students' higher-order mathematical competencies. Although the present study was limited to a specific mathematical topic and educational context, the positive findings suggest that the instructional framework may be applicable to broader mathematics learning settings with appropriate contextual adaptations. Overall, this study provides robust empirical evidence that the integration of the AMORA learning model and KOBIAS manipulative media represents an innovative and effective instructional strategy for strengthening elementary students' mathematical conceptual understanding while contributing to the ongoing development of learner-centered mathematics education.

AUTHOR CONTRIBUTIONS STATEMENT

Nina Rostiana Conceptualization, methodology, investigation, formal analysis, data curation, validation, visualization, writing original draft preparation, project administration, and corresponding author. Mubiar Agustin Conceptualization, methodology, supervision, validation, writing review and editing, interpretation of findings, and critical revision of the manuscript. Sandi Budi Irawan Conceptualization, methodology, supervision, validation, formal analysis, writing review and editing, visualization, and critical review of the manuscript. All authors contributed substantially to the conception and design of the study, approved the final version of the manuscript, and agreed to be accountable for all aspects of the work, ensuring the accuracy and integrity of the published research.

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