Vol. 10, No. 1 (2026) 119-134 ISSN: 2597-4866
Indonesian Journal of Primary Education

Development ISTOPAN: a manipulative learning media for improving conceptual understanding and supporting students' learning motivation in addition with regrouping

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Received 29 May 2026; First Revised 31 May 2026; Accepted 8 Juni 2026
First Available Online 1 June 2026; Publication Date 10 June 2026

Abstract

This study aimed to develop and evaluate the effectiveness of ISTOPAN, a manipulative and game-based learning media, in improving students' conceptual understanding of addition with regrouping and supporting their learning motivation. ISTOPAN was derived from the Indonesian concept "berhitung susun metode menyimpan" referring to a structured counting approach using the carrying (regrouping) method among first-grade elementary school students. The study employed a Research and Development (R&D) approach based on a simplified Borg and Gall model. The research subjects were first-grade students at SD Muhammadiyah 3 Gresik. Data were collected through questionnaires, classroom observations, interviews, and pre-test post-test assessments. Data were analyzed using descriptive qualitative and quantitative methods, supported by a paired-samples t-test to examine the effectiveness of the media. The result showed that ISTOPAN was valid, with validation scores of 95% from material experts, 94% from media experts, and 98% from learning experts. The initial field trial involving 8 students showed a response rate of 90%, with a significance value of 0.001 (< 0.05), indicating a significant improvement in students' understanding. The second field trial involving 17 students showed a response rate of 88.2%, with a significance value of 0.000 (< 0.05), confirming a statistically significant improvement in students' conceptual understanding. In addition, the findings indicates a positive impact on students' learning motivation, reflected in increased attention, interest, and active participation. In conclusion, ISTOPAN was valid, practical, and effective in improving conceptual understanding and supporting students' learning motivation.

Keywords: *ISTOPAN, mathematics learning media, learning motivation, conceptual understanding, carrying method.*

INTRODUCTION

Basic education played a crucial role in shaping children's cognitive development, character formation, and early critical thinking skills (Kartal et al., 2024; Sihombing et al., 2024). At the elementary level, especially in Grade 1, learning experiences significantly influenced student's long-term attitudes toward knowledge acquisition and problem-solving (Lee et al., 2024; AlJurdi & Salloum, 2025). Contemporary educational research emphasized that early mathematical learning should not only focus on procedural fluency but also foster conceptual understanding and learner engagement (Ncube & Luneta, 2025; McNeil et al., 2025). According to Piaget's cognitive development theory, students at this stage were in the concrete operational phase, where learning became more effective when abstract concepts were presented through concrete and meaningful representations (McLelland, 2024; Tosolini et al., 2025).

However, mathematics was often perceived as difficult at the elementary level because it was abstract and relied heavily on logical thinking. Column addition with regrouping was identified as one of the most challenging topics for first-grade students (Jensen et al., 2024; Mao et al., n.d.). To understanding this concept, students needed to grasp place value, number decomposition, and the reasoning behind the carrying process. Students who lacked sufficient conceptual understanding tended to perform calculations mechanically without fully understanding the process, which could negatively affect their future mathematical learning (Siregar et al., 2025).

Preliminary observation at SD Muhammadiyah 3 Gresik were conducted through a diagnostic test and classroom observation focusting on students' ability to solve addition problems with regrouping. The result revealed that 18 out of 25 first-grade students (72%) experienced difficulties in solving regrouping addition problem. The difficulties were identified based on students' incorrect answer in problems requiring carrying, particularly when adding units and tens. Approximately 65% of students frequently added units and tens separately without applying the carrying concept. Classroom observations further showed that many students were unable to explain their reasoning and relied on mechanical procedures. Interviews with the classroom teacher also indicated that students often made procedural errors and demonstrated a low level of conceptual understanding of place value. These findings indicated the need for instructional support that could bridge students' conceptual gaps.

One contributing factor to this issue was the A contributing aspect to this issue is the underutilization of limited use of instructional media that facilitated hands-on learning. Learning activities were still dominated by verbal explanation and symbolic representations, which were less suitable for students in the concrete operational stage (Handoko & Mubarikah, 2025; Puryati et al., 2025). Previous studies showed that the use of manipulatives and game-based learning could improve students' engagement and understanding (Ahmad & Siller, 2024; Siller & Ahmad, 2024). However, most existing learning media did not specifically address regrouping in column addition, nor did they integrate conceptual understanding and learning motivation within a single instructional design.

Although previous studies had demonstrated the benefits of manipulatives and game-based learning, these approaches generally focused on either conceptual understanding or learning motivation separately. In addition, existing media rarely provided structured support to help students connect place value concepts with the carrying process in regrouping. To address this limitation, the ISTOPAN learning kit was developed as an integrated learning medium combining visual representation, hands-on manipulation, and game-based activities. This integration enabled students to better understand regrouping concepts while actively engaging in the learning process. Therefore, ISTOPAN offered a more comprehensive approach by simultaneously improving conceptual understanding and supporting students' learning motivation. Furthermore, the ISTOPAN learning kit was created especially for first-graders who often struggle with carrying procedures (regrouping) and place value comprehension.

Based on these considerations, this study aimed to develop and evaluate the effectiveness of the ISTOPAN learning kit in improving students' conceptual understanding of addition with regrouping and supporting their learning motivation in Grade 1 at SD Muhammadiyah 3 Gresik.

RESEARCH METHODS

The Borg and Gall model was used as the Research and Development (R&D) design in this study. This methodology was well known for developing educational products through systematic and iterative processes. To accommodate the research context, time constraints, and the characteristics of primary school students, the original Borg and Gall model, which consisted of ten steps, was simplified into seven stages in this study.

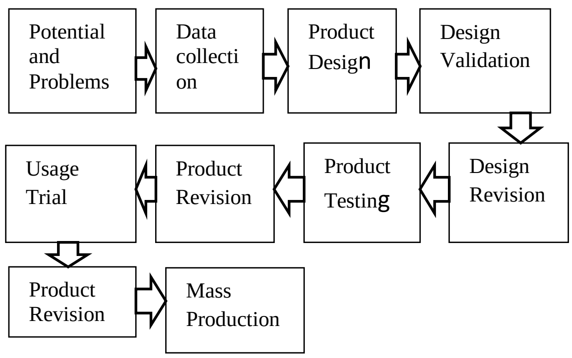

Figure 1.
Research and Development Procedure Borg and Gall Model
Source: (Sugiono, 2022), Metode Penelitian Kuantitatif, Kualitatif, dan R&D

Figure 1 showed the research and development procedure adapted from the Borg and Gall model. The stages implemented in this study included: (1) research and information gathering (need analysis), (2) planning, (3) product development, (4) expert validation and revision, (5) preliminary field testing (limited trial), (6) product revision and main field testing, and (7) final product development.

Due to limitations in the scope and duration of the study, several stages of the original model, such as operational field testing and dissemination were not fully implemented. While preserving the core principles of the Borg and Gall model, particulary the iterative cycle of development, validation, revision, and testing, the simplification was achieved by combining several closely related stages.

Previous educational development studies supported this modification, indicating that such adaptations remained methodologically acceptable as long as the essential processes of need analysis, product development, validation, revision, and field testing were maintained (Nawali et al., 2024; Rindrayani et al., 2025). Within the constraints of classroom-based research, this approach allowed the study to remain systematic and rigorous.

The overall research process began with identifying students' learning difficulties in regrouping. This was followed by the development of the ISTOPAN Learning Kit. After expert validation, the product was tested in a small group consisting of eight students, revised based on the findings, and subsequently implemented in a large group of 17 students to evaluate its effectiveness. This systematic process ensured that the final product was valid, practical, and effective for use in early mathematics learning.

This research was conducted at SD Muhammadiyah 3 Gresik, located in Gresik Regency, East Java, Indonesia. The school was selected based on the availability of appropriate research subjects, institutional support, and the relevance of the identified learning problem. Preliminary data indicated that 18 out of 25 first-grade students (72%) experienced difficulties in solving regrouping addition problems. The study was conducted from June 2025 to January 2026, covering all stages of development, including preliminary study, media development, expert validation, limited trials, field testing, and final product revision.

The study used three main types of data: media validity, media practicality, and media effectiveness. These data were collected using a mixed-methods approach, combining qualitative and quantitative techniques to provide a comprehensive evaluation of the developed media. The primary data sources included 25 first-grade students and one classroom teacher, Mrs. AD. Students provided data on conceptual understanding and learning motivation through tests and questionnaires, while the teacher provided data on media practicality and instructional feasibility through interviews. Expert validators assessed the quality and feasibility oh the media using structured validation instruments. The analysis Table 3 validation Instrumens (Material, Learning, and Media) is show in Table 1.

Table 1.
Analysis Table Three Validation Instruments (Material, Learning, and Media)

Component	Material Expert Instruments	Media Expert Instrument	Learning Expert Instruments
Validator	• Dr. Nur Fauziyah, M.Pd • Yusuf Wibisono, M.Pd	• Dr. Fatimatul Khikmiyah, S.Pd., M.Sc • Sukarto, M.Pd	• Ely Safanah, S,Si
Validation Date	July 18, 2025	July 21, 2025	July 23, 2025
Items	10 question	10 questions	10 questions
Rating Scale	Likert Scale 1-4	Likert Scale 1-4	Likert Scale 1-4
Scale Description	1: Strongly Disagree 2: Disagree 3: Agree 4: Strongly Agree	1: Strongly Disagree 2: Disagree 3: Agree 4: Strongly Agree	1: Strongly Disagree 2: Disagree 3: Agree 4: Strongly Agree
Indicators	• Alignment with Grade 1 Curriculum	• Visual appeal and characteristic	• Alignment with the

Component	Material Expert Instruments	Media Expert Instrument	Learning Expert Instruments
	Competencies (KD) • Appropriateness for students' cognitive development level. • Accuracy of mathematical concepts in ISTOPAN Learning Kit. • Clarity and correctness of learning materials. • Relevance to real-life situations and daily experiences • Logical and systematic sequence of content presentation. • Completeness of "carrying addition" (regrouping) materials. • Effectiveness of the media in improving concept understanding. • Relevance to students' learning motivation. • Appropriateness of language for Grade 1 elementary students	of first-grade elementary school students. • Readability (color, images, fonts) • Consistency of layout and visual elements. • Clarity of instructions for teachers and students. • Opportunities for active student interaction. • Alignment of the media with the goal of counting, arranging, and storing. • Technical functionality of media components • Compatibility with school facilities. • Safety of use for first-grade elementary school students. • Reusability and affordability of production costs.	characteristics of first-grade elementary school students. • Alignment of strategies with learning objectives. • Clarity of the ISTOPAN Learning Kit steps. • Alignment of methods with students' concrete thinking. • Ability to create active and enjoyable learning. • Alignment with the principles of meaningful learning. • Ease of implementation by teacher. • Appropriate time allocation • Increased motivation and interest in learning. • Alignment with an activity-based and concrete approach.

After mapping all aspects and rating items from the three validators in the table above, the next step is to determine the instrument's degree of validity. The formula for the feasibility percentage used is as follows:

$$P = \frac{\sum X}{\sum X_i} \times 100\%$$

Notes:
(P = Percentage, $\sum X$ = Total number of respondents' answers across all items, $\sum X_i$ = Total number of ideal scores for a single item, 100% : Constant)

The total score obtained from the observation sheets was then calculated as a percentage and converted based on the score interpretation criteria presented in Table 2.

Table 2.
Criteria for the Level of Validity According to Arikunto

Category	Percentage	Qualification	Equivalent
4	80%-100%	Valid	Eligible
3	60%-79%	Fairly Valid	Quite Eligible
2	50%-59%	LessValid	Less Eligible
1	0%-49%	Invalid	Not Eligible

Source: (Arikunto Suharsimi, 2017), Development of Research Instrument and Program Assessment.

The content validity of the assessment instruments for subject matter experts and media expert was analyzed quantitatively using Aiken's V coefficient (Kania et al., 2024; Ismarau Tajuddin et al., 2025). This test aimed to ensure the theoretical validity of each item before the instruments were used to evaluate the suitability of the ISTOPAN Learning Kit media. The mathematical formula underlying the calculation of Aiken's V index was presented as follows:

$$V = \frac{\text{s1} + \text{s2}}{2\text{x}(4-1)} = \frac{\text{s1} + \text{s2}}{6}$$

Notes: s1 = Validator score 1 - 1, s2 = Validator score 2 – 1)

A survey item was considered valid in terms of content if the value V ≥ 0.60.

Based on the decision criteria, a statement item was deemed valid and has a high level of consensus if the resulting coefficient was ≥ 0.60. After tabulating the data and reconstructing the calculations based on the evaluations of two subject matter experts and two media experts. Cronbach's Alpha coefficient was used to assess the internal consistency and reliability of the learning motivation questionnaire. An instrument was considered reliable if its Cronbach's Alpha value exceeded 0.70.

The assessment of students' understanding of mathematical concepts in the topic of regrouping addition and subtraction was based on four achievement indicators. The first indicator was students' ability to identify and restate the concept of place value (ones and tens). The second indicator involved the ability to distinguish between problem types that required regrouping techniques and those that did not. The third indicator focused on procedural aspects, namely students' accuracy in executing the regrouping addition and subtraction algorithm from the ones column and then carrying the tens remainder to the next column. The final indicator was the ability to transform word problem with everyday life themes into a vertical calculation mathematical model. These four indicators served as an absolute reference in the development of test items to ensure that the instrument could accurately record data on students' cognitive abilities.

A methodical and operational process that combined five primary instruments validation sheets, practicality questionnaires, interview guidelines, observation sheets, and achievement tests was used to gather data in this study. To establish a baseline of first-grade students' initial understanding of column addition with regrouping, a 30-minute pre-test was administered on the first day of the experiment. Subsequently, the instructional intervention using the ISTOPAN Learning Kit was conducted over three sessions totaling 210 minutes (70 minutes each). The researches acted as the classroom teacher and delivered instruction based on pre-validated lesson plans.

Concurrently, the regular classroom teacher used structured observation sheets to objectively record students' participation and interaction during each learning session. A 30-minute post-test was administered on the final day, immediately after the third session, to assess changes in students' conceptual understanding. In addition, practicality questionnaires were distributed, and semi-structured interviews with the classroom teacher were conducted to obtain reflective insights into the usability and pedagogical effectiveness of the media.

In accordance with Arikunto's (Arikunto Suharsimi, 2017) framework, which included data preparation, classification, and interpretation, descriptive qualitative techniques were used to analyse qualitative data obtained from interviews, expert feedback, and observation. During the initial stage, raw verbal data from interview transcripts and observation notes were collected, examined, and coded into specific thematic categories based on the research variables. For example, the code (LEARNING-CHALLENGE) was assigned to students learning difficulties, (STUDENT-ENGAGEMENT) to active hand-on participation, and (MEDIA-DESIGN-REVISION) to expert feedback related to the structural design of the media.

In order to cross-reference expert suggestions, teacher reflections, and classroom learning behaviours, these coded data were then methodically arranged into the tabulating or categorising step, where the qualitative inputs were translated into descriptive matrices and theme tables. In order to ensure a thorough and reliable conclusion regarding ISTOPAN learning kit mediaoverall instructional effectiveness, these emerging qualitative categories were synthesised with the quantitative achievement test score and practical percentages in the final stage of application and interpretation.

The media's efficacy was assessed using a thorough quantitative approach that went beyond basic significance testing. A Shapiro-Wilk normality test was carried out to confirm that the pre-test and post-test data had a normal distribution before doing the parametric paired-sample t-test (Amoah, 2025). After normality was confirmed, a paired-sample t-test was used to determine if student's conceptual knowledge had improved statistically significantly. Each student's normalised gain (N-gain) score was determined, classifying their development into high, medium, or low growth criteria in order to assess the exact amount and rate of learning improvement (Rahman et al., 2024). Additionally, Cohen's d effect size analysis was used to assess the degree and practical significance of the media's influence on learning outcomes, guaranteeing that ISTOPAN learning kit media efficacy was shown by both the absolute strength of its educational advancement and statistical significance (p = value).

In order to give a more thorough, multifaceted interpretation of the findings, the analytical framework of this study was closely matched with these quantitative measurements. It was based on constructivist learning theory (Piaget and Vygotsky) to describe how students' conceptual understanding developed throughout the shift from concrete to abstract mathematical operations thanks to the tactile, hand-on aspect of the medium (Bairy & Inamdar, 2026; Hadwen-Bennett et al., 2026). Self-Detemination Theory was also used to analyse shifts in students' intrinsic motivation and engagement, creating a theoretical connection between the learning media's interactive features and the noted enhancements in students' learning behaviours (Hartono, 2025; Fauzi, 2024).

RESULTS AND DISCUSSION

ISTOPAN (Berhitung Susun Metode Menyimpan) is an instructional tool that was created as a result of this study. With an emphasis on the mechanism of addition utilizing the regrouping technique, the product development process adhered to a methodical Research and Development (R&D) approach intended to connect abstract mathematical principles with early-level concrete operational thinking. Comprehensive results from three primary stages of development are presented in this section: (1) field diagnostics for initial needs assessment; (2) structural product design and formal expert validation; and (3) empirical testing that assesses the educational tool's practicality and field efficacy.

Preliminary Analysis and Needs Assessment

First-grade students and their classroom teacher at SD Muhammadiyah 3 Gresik participated in thorough field diagnostics to provide a strong empirical basis for creating the educational materials. This initial stage sought to identify the particular pedagogical bottlenecks that arise during early-grade mathematics education, assess student involvement levels, and record classroom reality methodically. Table 3 summarises the structured findings from direct classroom observations that describe the pupil behavioural and cognitive characteristics. After the student-side diagnostic, a semi-structured interview was conducted to get the teacher's perspective on practical teaching obstacles, current media constraints, and localized curriculum needs. These are presented thematically in Table 4.

Table 3.
Synthesis of Classroom Observation Findings and Instructional Needs

Observed Core Dimension	Empirical Classroom Reality (Findings)	Pedagogical Implications & Media Need.
Student Engagement &Focus	High boredom and distraction; students quickly lose interest during abstract calculation explanations	Requires a play-based, hand-on medium to sustain focus and curiosity.
Classroom	Passive, one-	Needs an

Observed Core Dimension	Empirical Classroom Reality (Findings)	Pedagogical Implications & Media Need.
Interaction	way communication; only a small fraction of students actively respond to the teacher.	interactive manipulative that fosters student-centred exploration and peer discussion.
Cognitive Profiles & Content Mastery	Severe difficulties grasping the abstract regrouping process of addition with carrying among diverse learners.	Demands an intuitive, text-free visual aid to model place values (tens and units) physically.

Table 4.
Diagnostic Summary of Teacher Interview and Practical Challenges

Diagnostic Theme	Synthesizes Teacher Response & Field Reality	Target Product Solution (ISTOPAN)
Current Instructional Approach	Reliance on traditional whiteboard explanations and abstract textbook exercises; no specialized manipulative media applied	Developing a portable, multi-component game box to transition from verbalism to concrete learning
Student Conceptual Hurdles	Grade 1 students frequently mix up units and tens, completely confusing the storage mechanism when a sum exceeds ten.	Integrating physically isolated slots for place values combined with interchangeable counting tokens
Existing Media Limitations	Basic objects (sticks/erasers) fail to visually represent the continuous process of dynamic regrouping.	Engineering dedicated tracking mechanism to physically show how ten individual units compile into one ten
Target Product Criteria	The teacher demands a simple, safe, durable, and highly appealing tool that students can independently manipulate.	Designing an ergonomic plywood and flannel suitcase featuring high visual clarity without distracting texts.

Product Design and Validation Result

The ISTOPAN Learning Kit medium was effectively developed as a portable, concrete-manipulative game box to address the challenges observed in early-grade mathematics education. The physical medium was constructed from a study board covered with durable and colorful flannel fabric, ensuring safety and ergonomic suitability for first-grade students. Specific compartments within the box represented place values (tens and units), mathematical operator spaces, and tangible colored tokens used in calculation activities. Figure 2 illustrated the detailed components and physical prototype of the develoed media.

Figure 2.
ISTOPAN Prototype

The instructional design prioritized intuitive student's involvement and avoided cognitive fatigue during mathematical manipulation by employing a clean, text-free visual environments, as illustrated in Figure 2. The regrouping process was represented through a physical exchange mechanism within the game pathway, which was systematically designed to guide students through the sequential stages of addition with carrying.

The interconnected components of the ISTOPAN learning materials were intended to facilitate addition with regrouping. The primary container for the media was designed to resemble a luggage. Tens and ones were represented by blue and brown stick, which were kept in flanel pockets on the left and right sides. The addition results were kept in a lower blue pocket. Number sticks for ones (yellow) and tens (red) were arranged in transparent boxes, which were also used to store the finished products. Answers were written on a mica-covered sheet at the bottom. Question card were kept in a white pouch in the middle, while usage guidelines were located at the bottom right. All things considered, each element served to help pupils grasp place value and the regrouping process through tangible manipulation.

The Instruction for using the ISTOPAN kit were as follows: (1) the kit was opened a problem card was taken from the problem card pocket; (2) the blue pencil sticks (valued at 10) were placed and arranged in the tens pocked, and the brown pencil sticks (valued at 1) were placed in the ones pocket according to the numbers on the problem card; (3) the number sticks were placed into the tens (red) and ones (yellow) glass boxes based on the numbers shown on the problem card; (4) the number of brown pencil sticks (ones) was counted; (5) if the number of ones exceeded 10, ten brown pencil sticks were exchanged for one blue pencil stick and placed in the upper tens pocked (storage); (6) the remaining brown pencil sticks were placed in the lower ones pocked; (7) the number sticks corresponding to the remaining brown pencil sticks were placed into the lower ones box (yellow); (8) the blue pencil sticks were counted and placed in the lower tens pocked, and the corresponding number sticks were placed in the tens box; (9) the final result was written on the answer board, after which the steps were repeated for the next problem.

A statement item was considered valid and to have a high degree of consensus if the resulting coefficient was ≥ 0.60, according to the decision criteria. The result of the instrument's content validity analysis were obtained after tabulating the data and carefully reconstructing the calculations based on the evaluations of two subject matter expert and two media experts, as presented in Table 5.

Table 5
Results of the Content Validity Analysis of the Subject Matter Expert and Media Expert Instruments

Evaluated Instrument	Subject Matter Expert Instrument	Media Expert Instrument
Number of Items	10	10
Score Range per item	3 - 4	3 - 4
Average Aiken’s V Index	0.95	0.93
Validity Status	Valid	Valid

Table 5 quantitatively extended the validation data and showed that the assessment tools had outstanding structural integrity. The average Aiken's V score for the Subject Matter Expert instrument was 0.95, while the average score for the Media Expert Instrument was 0.93. Aiken's validity criteria stated that extremely substantial content relevance was established by an index greater that 0.80. These figures demonstrated that both instruments were highly suitable, precise, and scientifically trustworthy for obtaining professional input on the development of the ISTOPAN learning kit media. Meanwhile, the assessment instrument of the learning expert was analyzed using a qualitative-descriptive approach due to the presence of a single validator. Based on the learning expert's observation sheet, it was concluded that the instrument covered all indicators of the concrete approach for early grades and was ready for implementation to collect feasibility data minor revisions were made to the time allocation for students learning activities.

The panel of professional judges formally assessed the conceptual and physical prototype of the ISTOPAN learning kit after the structural confirmation of the research instrument. A Subject Matter Expert, a Media Expert, and an instructional Learning Expert conducted thorough evaluations as part of the validation process. Table 6 presented the combined result of the expert validation percentages and their corresponding feasibility categories in a systematic manner.

Table 6.
Product Validation Results from Expert Judges

Validation Expert	Aspect	Final Percentage (%)	Feasibility Category
Subject Matter Expert	Curricular Alignment, Conceptual Accuracy, Language Clarity, Contextual Relevance	95.00%	Valid
Media Expert	Produc Aesthetics, Visual Layout, Ergonomics, Early-Grade Safety, Technical Functionality	94.00%	Feasible
Learning Expert	Instructional Strategy, Play-based Sequencing, Time, and Student Motivation	98.00%	Valid
		95.67% Average Validation	Highly Feasible

ISTOPAN learning kit satisfies the strict requirements for early-grade educational media, as shown by the empirical readouts shown in Table 6. A final validation rate of 95.00% was given by the subject matter expert, indicating excellent language clarity suited to early childhood understanding and flawless conformity with the first-grade curriculum. The physical suitcase arrangement is completely ergonomic, devoid of potentially dangerous structural edges, and very visually appealing for young learners, according to the media validation, which achieved a 94.00% feasibility score. Additionally, the instructional design methodical math game route effectively simulates the tangible practical thought required for addition with carrying (regrouping).

ISTOPAN is empirically categorised as highly feasible with a cumulative average validation score of 95.67%. The generated educational prototype is structurally solid, educationally impactful, and fully prepared to be implemented in upcoming student-side practicality and effectiveness trials, according to the collective expert consensus.

Despite the extremely high validation score shown in Tabel 5 and 6, the expert validators offered a number of helpful suggestions to improve the ISTOPAN Learning Kit. These changes were thought to be crucial as part of the iterative product development process. The researcher revised the instructions by substituting simpler terminology for complicated phrases and rearranging them into clearer, more sequential phases after the media expert recommended reducing the instructional language. In order to lessen possible misunderstanding, the researcher increased colour contrast and offered better visual signals. Improvements in visual clarity were also advised, especially in separating hues that reflect place values. Several issue card were revised utilizing more recognisable real-life circumstances as a consequence of the subject matter expert's feedback, which underlined the need to increase contextual relevance. In order to better promote steady learning development, the learning expert also recommended improving time allocation and activity sequencing, which promoted changes to instructional flow. In the end, these changes produced a more aesthetically pleasing, pedagogically sound, and user friendly learning tool, guaranteeing that the ISTOPAN Learning Kit was not only practical but also more in line with the developmental requirements of young children.

An initial use trial (N = 8) and an extended field test (N = 17) were the two consecutive deployment stages used to assess the empirical utility of ISTOPAN kit after the product was formally validated. Five psychological macro-indicators that represent the media's direct influence on first-grade students' motivation as well as its practical applicability have been created from the individual questionnaire scores. Table 7 provides a methodical framework for this thorough analysis of user answers from both testing phases.

Table 7.
Student Practicality and Learning Motivation Profiles

Evaluation Indicators	Initial Use Trial (N = 8)	Field Test (N= 17)	Empirical Category
Attention and Aesthetic Appeal	88.75%	86.00%	High/ Positive
Usability and Instructional Clarity	95.00%	89.00%	High/ Positive
Active Engagement and Interaction	87.50%	89.25%	High/ Positive
Intrinsic Joy of Learning	91.25%	90.50%	High/ Positive
Instructional Pacing and Alignment	87.50%	86.25%	High/ Positive
	90.00% Average	88.20% Average	High/ Positive

The longitudinal percentages presented in Table 7 showed that the ISTOPAN kit was a highly useful instrument that also increased students' learning motivation. The total index reached 90.00% during the first trial and remained relatively consistent at 88.20% during the expanded field testing. The usability and clarity characteristics received the highest rating (95.00%), demonstrating that first-grade pupils were capable of navigating the game grid independently without the need for complex written instructions, thus preventing cognitive fatigue.

Qualitative field data gathered during classroom observations provided significant support for the quantitative indicators of student involvement and enjoyment in learning. The conventional, passive whiteboard routine was successfully transformed into an active learning environment through the physical manipulation of tangible tokens using the storage grid. During the post-trial diagnostic interview, the first-grade classroom teacher specifically mentioned this pedagogical change and stated: "Students who usually daydream and sit passively during conventional math lessons became very enthusiastic; they jostled one another and eagerly moved the number tokens on their own from the ones pocket to the tens track on the left."

This qualitative finding demonstrated that the ISTOPAN kit's physical, text-free design effectively met children's psychological needs during the concrete operational phase. The medium maintained students' attention, reduced arithmetic anxiety, and transformed the regrouping process into a fun, student-centered classroom experience by turning abstract addition rules with carrying into an engaging game.

Learning Effectiveness and Conceptual Understanding Results

The final stage of the empirical assessment measured how effectively the ISTOPAN kit improved students' conceptual understanding of addition with regrouping. Descriptive student achievement data, the normalised gain score (N-Gain) for conceptual progress, and the inferential Paired Samples T-Test results were combined into a comprehensive statistical analysis. Table 8 presented the complete academic synthesis from both the initial trial and the primary field test in a systematic manner.

Table 8.
Comprehensive Statistical Summary of Learning Effectiveness and Conceptual Growth

Statistical Parameter	Initial Use Trial (N = 8)	Field Test (N = 17)
Pre-Test Descriptive Metrics		
Mean Score	60.00	62.35
Standard Deviation (SD)	11.25	12.04
Minimum/ Maximum Score	20 / 80	40 / 80
Classroom Mastery Percentage	62.5%	41.0%
Post-Test Descriptive Metrics		
Mean Score	87.50	85.88
Standard Deviation (SD)	8.12	9.39
Minimum/ Maximum Score	80 / 100	60 / 100
Classroom Mastery Percentage	100.0%	88.0%
Conceptual Growth & Inferential Testing		
Mean Normalized gain (N-Gain)	0.69 (Medium)	0.62 (Medium)
T-Value	5.291	7.412
Degrees of Freedom	7	16
Significance level	0.001	< 0.001
Cohen’s d (Effect Size)	1.87 (Large)	1.58 (Large)

The comprehensive statistical profile presented in Table 8 demonstrated that the incorporation of the ISTOPAN kit led to substantial mathematical progress. The mean mathematics comprehension score increased from 60.00 to 87.50 in the initial trial involving 8 students, achieving a perfect 100% classroom mastery level. In the large field test involving 17 diverse learners, the pre-test baseline stood at a low 62.35 with a modest 41% mastery rate, which revealed significant initial misunderstandings of the carrying mechanism (regrouping). Nevertheless, the post-test mean increased to 85.88 after the play-based manipulative intervention, which raised overall student proficiency to 88%.

The normalised gain was computed to assess the rate of this academic advancement. The N-Gain indices from the first trial (0.69) and the main field test (0.62) consistently fell within the Medium Growth category, which indicated a stable and reliable increase in mathematical comprehension across different student groups.

The paired samples t-test result confirmed the inferential validity of this growth. The analysis produced a high t-value of 7.412 with a significance level (p-value) of 0.001 for the primary field test. The null hypothesis was rejected, as the p-value was much lower than the conventional alpha threshold (alpha = 0.05). This demonstrated that the change from a low pre-test baseline to a high post-test score was statistically significant and was directly caused by the educational intervention rather than by external factors.

The results of this study proved that the ISTOPAN learning kit was valid, feasible and effective in improving Grade 1 students' conceptual understanding of addition with regrouping. However, beyond confirming its effectiveness, it was also important to explore how the specific elements of the media contributed to students' learning processes.

The ISTOPAN learning kit was effective in its ability to concretise abstract mathematical concepts, particularly place value (ones and tens) and the regrouping process. The physical features of the media, such as the boxes for units and tens, movable objects, and structured activity cards, acted as representational tools that linked symbolic and concrete understanding. Students were not simply performing procedural addition but rather manipulating objects to represent numerical values. Through this process, they recognised how ten units regrouped to form one ten, which strengthened their conceptual understanding rather than merely memorising algorithms. The finding was consistent with previous studies that emphasised the role of manipulatives in fostering mathematical understanding (Ahmad & Siller, 2024; Yudt, K. E., Sawyer, B. E., & Shera, n.d.). in addition, these outcomes aligned with recent literature highlighting the importance of validated learning media that bridge theoretical design and classroom implementation. Studies by (Annuar & Solihatin, 2025) demonstrated that learning media grounded in cognitive and developmental appropriateness consistently improved student engagement and conceptual acquisition in mathematics.

Constructivist learning theory, which emphasises that knowledge is actively constructed through interaction with real experiences, was consistent with these finding (Al Abri et al., 2024; Almojallas et al., 2026). The manipulatives embedded in the ISTOPAN learning kit supported deeper cognitive processing by enabling students to transition from enactive (hand-on) experiences to symbolic understanding. By linking actions, representations, and mathematical symbols, this approach promoted meaningful learning in contrast to traditional instruction, which frequently emphasised procedural knowledge.

The findings showed that the ISTOPAN learning kit enhanced students' motivation to learn, particulary in terms of attention, enthusiasm, engagement, and self-confidence. During learning activities, students demonstrated sustained focus and active participation, while the interactive and game-based features fostered engagement and supported independent problem-solving. These conditions increased students' confidence, as they were able to directly manipulate learning materials to explore and correct their understanding. This result was consistent with motivational theories suggesting that stimulating and interactive learning environments significantly enhance student engagement and learning motivation.

Furthermore, the use of interactive media and manipulatives was found to improve both student engagement and mathematical achievement, aligning with previous studies. However, this study extended prior research by integrating cognitive and affective outcomes into a single, low-cost, and contextually relevant instructional medium. The ISTOPAN learning kit demonstrated that, in early-grade mathematics education, conceptual understanding and learning motivation could be developed simultaneously through structured, hands-on learning experiences.

This work made a significant contribution to the advancement of basic mathematics education by offering an instructional medium that was particularly created to enhance the teaching of addition with regrouping and has been experimentally validated. In order to address frequent student challenges with place value and regrouping ideas, it provided a useful approach for combining tangible manipulatives with methodical instructional design. Additionally, by showing how developmentally approapriate, play-based learning materials might successfully close the gap between abstract mathematical ideas and children cognitive preparation in early primary school, this study added to the body of information already in existence

CONCLUSION

This study aimed to develop and evaluate the ISTOPAN kit learning media in terms of validity, practicality, and their potential to improve students' conceptual understanding while supporting their learning motivation. The findings indicated that the media were valid based on expert evaluation and practical based on positive responses from teachers and students.

The students' post-test scores were higher than their pre-test scores, indicating positive improvement following the implementation of the ISTOPAN media (p 0.05) with an N-Gain values in the moderate to high category. Moreover, the media supported students' learning motivation, as reflected in increased attention, interest, and active participation in learning activities. In term of conceptual understanding, students demonstrated improvement in key indicators including understanding place value, performing regrouping, and representing mathematical concepts concretely.

However, this study had several limitations. The sample was limited to a single class of first-grade students, and the implementation was conducted over a short-term period. The study also focused only on addition with regrouping and did not examine other mathematical operations or long-term retention effects. Furthermore, as the research employed a one-group pretest-posttest design without a control group, the findings indicate improvement after the implementation of the ISTOPAN media but do not allow for strong causal or comparative conclusions regarding its effectiveness.

Based on these findings, future research was recommended to involve larger and more diverse samples, develop lighter and more flexible versions of the media to improve the usability, expand the media to cover other mathematical topics, and integrate the media with digital technology to enhance its instructional potential.

In cloclusion, the ISTOPAN kit learning media has the potential to improve students conceptual understanding of addition with regrouping and to support their learning motivation; however, further research with more rigors design is required to confirm its effectiveness.

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