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Original Article

Development and Validation of Learning Intervention Material in Adding and Subtracting Integers Using Modified ADDIE Model

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Abstract. Persistent challenges in learning integer operations continue to hinder foundational numeracy among Filipino learners, as evidenced in both classroom assessments and national learning indicators. While several instructional programs exist, there remains a lack of systematically designed and validated intervention materials that directly address the most common misconceptions in integer addition and subtraction. This gap limits teachers' ability to remediate conceptual errors using evidence-based tools. The present study aimed to develop, validate, and evaluate a contextualized learning intervention material—the COCO-Abacus—to strengthen Grade 7 learners' understanding of integer operations. Guided by a modified ADDIE model, the study employed a developmental research design integrating needs analysis, expert validation, classroom implementation, and evaluation. Data collection involved an established integer operations test, a content validation instrument, and a learner motivation survey. Through this process, the intervention was refined and implemented to assess its effectiveness and acceptability. Findings indicated that the COCO-Abacus effectively addressed key misconceptions involving signs, directionality, and zero-pair reasoning. Learners demonstrated improved conceptual understanding and procedural fluency, while experts affirmed the material's clarity, accuracy, and pedagogical soundness. Learners also reported strong engagement and perceived the material as useful. The study concludes that a representation-rich, manipulative-based approach can meaningfully enhance students' mastery of integer operations. It is recommended that similar evidence-based materials be integrated into mathematics instruction to strengthen foundational numeracy and support diverse learning needs.

Keywords: *COCO-Abacus; Effect size; Integer operations; Modified ADDIE model; Mathematics education.*

Mastery of integer addition and subtraction is a fundamental skill in mathematics, yet many Filipino learners struggle with these operations, creating barriers to higher-level learning. International assessments highlight the severity of this issue. In PISA 2022, the Philippines scored 355 points in mathematics, far below the OECD average of 472. More critically, only about 16% of Filipino students reached at least Level 2 proficiency, while the majority remained below Level 1, indicating serious gaps in basic numeracy (OECD, 2023). Similarly, the TIMSS 2023 results reaffirm these challenges, with Filipino students performing significantly below the international average in both mathematics and science. TIMSS also reported widening achievement gaps and persistent difficulties in fundamental concepts among lower-performing countries, including the Philippines (Davier et al., 2024).

The persistent gaps in foundational numeracy revealed by PISA 2022 and TIMSS 2023 underscore the urgent need to improve the quality and equity of mathematics learning in the Philippines. This concern directly aligns with Sustainable Development Goal 4 (Quality Education), particularly SDG 4.1, which calls for ensuring that all learners acquire foundational skills, and SDG 4.5, which emphasizes reducing disparities in learning outcomes. By addressing widespread misconceptions in integer operations and supporting evidence-based instructional materials, this study contributes to advancing inclusive and equitable quality education within the Junior High School mathematics context.

In the Philippine curriculum, integer operations are introduced in the upper elementary grades and reinforced in Grade 7, which is part of Junior High School. At this stage, learners are expected to master addition and subtraction of integers as gateway skills for more advanced topics such as algebra, equations, and linear functions—making conceptual understanding of integers curriculum-critical. However, classroom observations and diagnostic assessments reveal persistent misconceptions, including confusing the minus sign as an operation versus a negative sign, failing to apply the rule for subtracting a negative integer, and memorizing procedures without using representations like number lines or counters (Rosyidah et al., 2021; Seigler & Lortie-Forgues, 2015). These difficulties hinder learners' ability to transition from concrete to abstract reasoning (Piaget, 1973), which is essential for success in higher-level mathematics.

The Department of Education (DepEd) has launched initiatives such as the National Learning Camp and the POEM-MTAP Saturday Program to address learning losses and strengthen foundational skills. While these programs provide structured support, the availability of intervention materials that are (i) systematically designed using instructional design models, (ii) validated for content and usability, and (iii) specifically targeted to integer misconceptions remains limited and poorly documented in the local context. This gap underscores the need for evidence-based resources that not only remediate errors but also align with curriculum standards and best practices in instructional design. As emphasized by Manaligod (2023), these materials should undergo multiple stages of evaluation—particularly content validation—to ensure their accuracy, relevance, and instructional effectiveness.

This research addresses the gap by developing an intervention material based on a modified ADDIE model, validating content through expert review using Content Validity Index (CVI), and assessing usability and motivational impact through learner feedback. Furthermore, the study evaluates the intervention's effectiveness using a pre-test–post-test design, providing empirical evidence of its impact on conceptual understanding and procedural fluency. By integrating design rigor, validation, and effectiveness testing, this study contributes a replicable framework for improving foundational numeracy in Junior High School mathematics.

Methodology

Research Design

This study employed a developmental research design that integrated quantitative approaches to systematically develop, validate, and evaluate a learning intervention for teaching Grade 7 students how to add and subtract integers. The process was anchored on a modified ADDIE instructional design model, which consolidated the five traditional phases into three practical stages—Analysis; Design, Development, and Validation; and Implementation and Evaluation—as illustrated in Figure 1. This modification streamlined the research workflow while preserving the iterative and systematic nature of ADDIE, consistent with its use as a flexible instructional design framework (Molenda, 2003; Branch, 2009). Its non-linear and iterative nature allows designers to reorganize or combine phases according to project needs (Lasky, 2024; Bouchrika, 2026).

In this study, the Analysis phase focused on identifying learners' misconceptions and challenges in integer operations through a diagnostic pre-test. The results informed the learning gaps and guided decisions regarding content, activities, and instructional strategies. The Design and Development phase involved creating the learning intervention material based on the analysis results. This stage included drafting lessons and manipulative-based activities, preparing the interactive workbook, and refining the material through expert evaluation using DepEd LRMDS criteria. Revisions in response to expert feedback ensured the material's clarity, accuracy, and usability before classroom implementation.

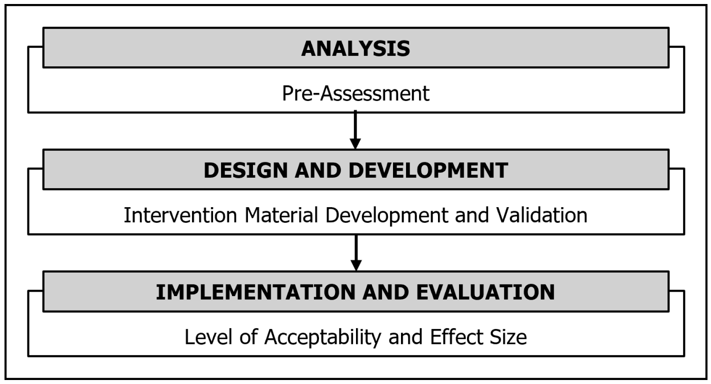

Figure 1. *Instructional Design Model of the Study*

Finally, the Implementation and Evaluation phase consisted of delivering the validated material to the selected Grade 7 learners and determining its effectiveness through a one-group pre-test–post-test design. The pre-test established baseline proficiency, while the post-test measured changes in conceptual understanding after the intervention. Quantitative analyses determined statistical significance and effect size, and qualitative feedback from experts and learners informed the material's validity and acceptability.

Participants and Sampling Technique

The study was conducted in a public national high school in Santiago City, where a purposive sampling technique was used to select Grade 7 learners who continued to struggle with adding and subtracting integers based on diagnostic and post-assessment results. Although purposive sampling is non-probability, the use of inferential statistics—specifically the paired samples t-test—is justified because the analysis focuses on the same group of learners measured twice (pre-test and post-test), making the comparison within-subjects rather than between different samples. Since the objective is to determine whether the intervention produced a significant improvement among these identified learners, and not to generalize findings to a broader population, inferential statistics remain appropriate and valid for this developmental research design. Initially, the teacher-researcher administered a diagnostic assessment to all Grade 7 students to determine their level of understanding of integer operations. After teaching the competency, a post-assessment was conducted to identify students who continued to struggle with misconceptions. These learners were chosen as the primary respondents for the implementation phase of the study.

In addition to learner respondents, five experts participated in validating the developed learning intervention material. The panel consisted of one Education Program Supervisor in Learning Resources, one in Mathematics, one Master Teacher, and two experienced mathematics teachers. Their evaluation ensured that the material was pedagogically sound, aligned with curriculum standards, and effective for teaching integer operations. Expert validation is a critical step in instructional material development to guarantee quality and relevance (McKenney & Reeves, 2025). Furthermore, learner respondents completed the Instructional Materials Motivation Survey (IMMS) to assess the acceptability of the developed material. The IMMS evaluated dimensions such as engagement, relevance, confidence, and satisfaction, providing insights into the intervention's motivational impact and usability (Keller, 2010).

Research Instruments

Integer Test of Primary Operation – Pre-Test and Post-Test

The Integer Test of Primary Operations (ITPO) was utilized as the primary assessment tool to measure students' prior knowledge and performance in adding and subtracting integers. The ITPO is a validated instrument specifically designed for assessing integer operations and has demonstrated strong reliability and validity (Nurnberger-Haag et al., 2022). In its original validation, researchers conducted a Rasch analysis with a sample of 187 middle school students, confirming good person and item fit, which ensures accurate measurement of learners' skills. The study reported high internal consistency, with a Cronbach's alpha coefficient of 0.87, indicating excellent reliability for the instrument.

The ITPO assesses three dimensions: addition, subtraction, and multiplication/division of integers. For this research, only the addition and subtraction components were used, as these are the focus competencies. Using ITPO provides a standardized and reliable basis for evaluating the effectiveness of the developed learning intervention material. Pre-test scores established baseline proficiency, while post-test scores measured improvement after the intervention, enabling computation of statistical significance and effect size.

Learning Intervention Material

The primary instrument in this study was a learning intervention material developed using the ADDIE model to help Grade 7 students master the addition and subtraction of integers. The design and development of the material were planned based on the analysis of learners' misconceptions and challenges identified during the initial phase of the study. These misconceptions—such as confusion about sign rules, difficulty with subtracting negatives, and a weak understanding of additive inverses—guided the selection of instructional strategies and content features. The material incorporated contextualized lessons, visual aids, and manipulative-based activities to strengthen conceptual understanding and reduce reliance on rote memorization. To ensure systematic progression, the following suggested lessons, adapted and modified from Sahat et al. (2018), were considered. These lessons served as a framework, but were implemented only if they aligned with the results of the analysis phase:

Table 1. *Suggested Intervention Lessons to be Included in the Interactive Workbook*

Lesson	Focus
1	Differentiation and Reinforce the Difference Between Signs and Operations
2	Introduce the Learning Manipulative
3	Introduction and Activities Using Manipulative to Addition of Integers
4	Guided Discovery of the Rule in Adding Integers
5	Introduction and Activities Using Manipulative to Subtraction of Integers
6	Guided Discovery of the Rule in Subtracting Integers
7	Reinforcement Activities and Exercises Related to Addition and Subtraction of Integers

Expert Validation Checklist

The developed learning intervention material and its accompanying interactive workbook were validated using the Guidelines and Processes for LRMDS Assessment and Evaluation prescribed by the Department of Education for instructional resources. This evaluation tool assesses materials based on three key factors: content quality, other findings, and additional manipulative requirements. Each factor has a threshold score that must be met for the material to be considered satisfactory. Materials rated as "Passed" are recommended for classroom use, while those rated "Failed" require revision. This validation process ensures that the learning intervention material is pedagogically sound, aligned with curriculum standards, and suitable for enhancing Grade 7 learners' skills in adding and subtracting integers.

Level of Acceptability

The Instructional Materials Motivation Survey (IMMS) was used to assess the acceptability of the developed learning intervention material among its users. The IMMS is a validated instrument based on Keller's ARCS model, which measures four dimensions of learner motivation and engagement: Attention, Relevance, Confidence, and Satisfaction (Keller, 2010). This tool provided insights into how well the material was received by students and its potential impact on their learning experiences. High scores in these dimensions indicate that the material is perceived as engaging, useful, and supportive of learners' confidence in mastering integer operations.

Data Gathering Procedure

Initial Phase

Before implementing the modified ADDIE process, the researcher sought formal permission to conduct the study. This involved drafting and submitting a request letter and permit to conduct to the Schools Division Superintendent of the Schools Division Office of Santiago City, clearly outlining the purpose, objectives, and significance of the research. The letter was accompanied by the research proposal and other required documents to ensure transparency and compliance with institutional protocols. Approval from the school administration was secured prior to proceeding with the subsequent phases of the study.

Analysis
The first phase focused on identifying misconceptions and challenges experienced by Grade 7 learners in adding and subtracting integers. A diagnostic pre-test using the Integer Test of Primary Operations (ITPO) was administered to the respondents. This test aimed to determine baseline proficiency and uncover common errors in integer operations. The results provided quantitative data that served as the foundation for designing the intervention and for comparing future performance. This phase laid the groundwork for the instructional design process by defining the learning problem, identifying needs, and setting clear goals for developing the learning intervention material.

Intervention Material Design, Development, and Validation
In this phase, the learning intervention material and its accompanying interactive workbook were prepared based on the results of the Analysis phase. The content was designed to address the misconceptions identified in the pre-test and aligned with curriculum standards. The material included structured lessons, contextualized activities, and reinforcement exercises to help learners master the addition and subtraction of integers. To ensure quality and compliance with educational standards, the developed material was validated by experts using the DepEd Learning Resource Management and Development System (LRMDS) guidelines. The panel of experts evaluated the material for content accuracy, instructional design, and technical design. Feedback was collected, and necessary revisions were made until the material achieved a "Passed" rating, confirming its suitability for classroom implementation.

Level of Acceptability and Effect Size
In this phase, the validated learning intervention material and interactive workbook were implemented with the selected Grade 7 respondents. The implementation followed a structured schedule of activities, as outlined in the intervention lessons included in the workbook. Delivering the intervention over multiple sessions ensured sufficient exposure and active engagement with the material, promoting deeper learning. After the implementation, a post-test using the Integer Test of Primary Operations (ITPO) was administered to measure changes in learners' performance. The pre-test and post-test scores were analyzed to determine improvement in proficiency. A paired t-test was used to assess statistical significance, and Cohen's d was computed to determine the effect size of the intervention.

To assess the acceptability of the learning materials, the Instructional Materials Motivation Survey (IMMS) was administered to respondents. Based on Keller's ARCS model (Attention, Relevance, Confidence, Satisfaction), the IMMS provided insights into learners' perceptions of the material's engagement, usefulness, and motivational impact. Responses were collected and analyzed to determine the overall level of acceptability among users.

Data Analysis Procedure
The data gathered for this study were processed using the Statistical Package for Social Sciences (SPSS), employing a variety of descriptive and inferential tools to evaluate both the learning materials and student performance. Initially, descriptive statistics, specifically frequency counts and percentages, were used to analyze diagnostic pre-test results to identify common misconceptions in integer operations. This was followed by validation of the learning intervention material using the mean, standard deviation, and the Content Validity Index (CVI). Five experts rated the material against DepEd standards, with a Content Validity Index (I-CVI) of 0.78 or higher required to ensure it met the necessary thresholds for relevance and clarity.

To assess the impact of the intervention on student learning, the researchers calculated the mean and standard deviation of scores before and after the implementation. These results were interpreted in accordance with the proficiency levels prescribed by DepEd Order No. 73, s. 2012, ranging from "Beginning" to "Advanced." To determine whether the changes in student performance were statistically significant, a paired-samples t-test was conducted. Furthermore, Eta-squared was used to calculate the effect size, which was then interpreted using Cohen's d values to categorize the magnitude of the intervention's impact as negligible, small, medium, or large.

Finally, the study evaluated the level of acceptability of the COCO-Abacus using the Instructional Materials Motivation Survey (IMMS). Descriptive statistics were used to analyze user ratings across four motivational components: Attention, Relevance, Confidence, and Satisfaction. These ratings, collected on a five-point Likert scale, provided an average weighted mean that determined the intervention's level of acceptability. By combining these statistical methods, the study provided a comprehensive analysis of the intervention's validity, its effectiveness in improving mathematical skills, and its overall reception among the target users.

Ethical Considerations

This study adhered to established ethical standards throughout the research process. Before data collection, formal approval to conduct the study was obtained from the school administration, and informed consent from parents or guardians and assent from learner-participants were secured. During data collection, participation remained voluntary, with respondents informed of their right to withdraw at any time without penalty. Confidentiality and anonymity were strictly observed by ensuring that no identifiable information was collected and limiting access to the raw data to the researcher only. After data gathering, all information was stored securely and used solely for research purposes, with only aggregated results reported to ensure that individual identities could not be traced. These measures ensured that ethical considerations were upheld at every stage of the study.

Results and Discussion

Analysis

The first phase of the modified ADDIE process focused on diagnosing learners' difficulties in adding and subtracting integers. A pre-test was administered to Grade 7 students to establish baseline proficiency and identify common error patterns. This diagnostic step provided essential data on misconceptions that hinder conceptual understanding and procedural fluency. The results guided the design and development of the intervention material by highlighting specific areas where learners struggle, such as sign interpretation, subtracting negative integers, and applying rules without visual representation.

Misconception of Grade 7 Students in Adding and Subtracting Integers

Table 2 presents the number and percentage of correct and incorrect responses for each of the 20 pre-test items on integer addition and subtraction. The overall wrong rate is 46.59%, with a mean score of 10.68 out of 20. Items involving subtracting negative integers and operations requiring sign transformation recorded at the highest error rates—Item 10 (77.27%), Item 6 (72.73%), and Item 20 (68.18%). In contrast, items involving additive inverses (Items 14 and 15) had lower error rates (22.73%).

Table 2. *Item-Level Performance (Pre-Test)*

Items	Wrong (n)	Wrong (%)	Correct (n)	Correct (%)
1. $(-2) + (-5)$	3	13.64%	19	86.36%
2. $2 + (-3)$	8	36.36%	14	63.64%
3. $(-2) + 3$	10	45.45%	12	54.55%
4. $16 - 23$	9	40.91%	13	59.09%
5. $(-13) + 8$	7	31.82%	15	68.18%
6. $2 - (-3)$	16	72.73%	6	27.27%
7. $(-16) + 23$	9	40.91%	13	59.09%
8. $12 - 15$	13	59.09%	9	40.91%
9. $(-3) - (-2)$	8	36.36%	14	63.64%
10. $(-8) - 13$	17	77.27%	5	22.73%
11. $3 + (-6)$	8	36.36%	14	63.64%
12. $(-2) - (-5)$	14	63.64%	8	36.36%
13. $(-2) + (-3)$	12	54.55%	10	45.45%
14. $15 + (-15)$	5	22.73%	17	77.27%
15. $(-12) + 12$	5	22.73%	17	77.27%
16. $17 - (-25)$	13	59.09%	9	40.91%
17. $(-3) - 2$	14	63.64%	8	36.36%
18. $(-5) + 7$	6	27.27%	16	72.73%
19. $(-5) - (-2)$	13	59.09%	9	40.91%
20. $(-3) - (-6)$	15	68.18%	7	31.82%

The data suggest that learners struggle most with rules involving negative signs, particularly when subtracting negatives and determining the correct sign in operations. These errors indicate that students rely heavily on memorization rather than conceptual understanding. The pattern implies a need for instructional approaches that emphasize clear differentiation of positive and negative values, step-by-step demonstrations of sign rules, and structured practice opportunities to reinforce correct procedures.

Research supports the idea that integer operations are conceptually challenging due to their abstract nature

(Seigler & Lortie-Forgues, 2015). Misconceptions often stem from confusion between signs and operations, as noted by Rosyidah et al. (2021) and Khalid and Embong (2019). Constructivist and experiential learning theories (Piaget, 1973; Kolb, 1984) recommend hands-on activities and visual representations to address these gaps. Strategies such as color coding to distinguish signs, guided discovery exercises, and interactive reinforcement tasks have been shown to improve understanding of integer operations—features that align with best practices in mathematics education.

Table 3. *Misconception Prevalence (Grouped by Item Type)*

Misconception	Items	Students with ≥1 error (n)	Prevalence (%)
M1 Subtracting a Negative => Addition	6, 9, 12, 16, 19, 20	21	95.45%
M5 Negative Minus Positive => More Negative (Direction Error)	10, 17	18	81.82%
M2 Adding Unlike Signs (Choose Sign by Magnitude)	2, 3, 5, 7, 11, 18	17	77.27%
M3 Simple Subtraction Crossing Zero => Negative Result	4, 8	14	63.64%
M4 Additive Inverses / Zero Pairs => 0	14, 15	9	40.91%

Table 3 summarizes five major misconceptions identified in the pre-test. The most prevalent misconception (M1: failing to convert subtracting a negative into addition) affected 95.45% of students, followed by M5 (direction errors when subtracting a positive from a negative) at 81.82%, and M2 (incorrect sign choice when adding unlike signs) at 77.27%. Misconceptions related to crossing zero (M3) and additive inverses (M4) were less frequent but still significant at 63.64% and 40.91%, respectively.

The dominance of M1 and M5 indicates that learners have difficulty applying integer rules. Nearly all students made at least one error in items requiring sign transformation, suggesting that symbolic instruction alone is insufficient. The prevalence of M2 further implies that learners lack strategies for comparing absolute values when adding integers of different signs. These findings highlight the need for visual cues, contextualized examples, and progressive exercises that connect abstract rules to concrete representations.

Studies confirm that misconceptions in integer operations persist even after instruction, often due to inadequate conceptual support (Rosyidah et al., 2021; Harun et al., 2023). International assessments like PISA and TIMSS also report similar gaps among Filipino learners (OECD, 2023; Mullis et al., 2020). Effective remediation strategies include manipulative-based activities, color-coded representations, and structured reinforcement tasks, which are consistent with recommendations from the National Council of Teachers of Mathematics (2000) and experiential learning frameworks (Kolb, 1984). These approaches can help learners visualize operations and internalize rules, reducing reliance on rote memorization.

Design and Development of the Intervention Material to Address Misconceptions

The design and development of the learning intervention material were guided by the ADDIE model, ensuring a systematic approach to instructional planning. The Analysis phase identified common misconceptions among learners, including confusion between signs and operations, difficulty with subtracting negative integers, and a weak understanding of additive inverses. These findings informed the design decisions and instructional strategies integrated into the material.

Design Phase

The structure of the intervention was based on adapted and modified lessons by Sahat et al. (2018), organized into seven sequential lessons. These lessons were planned to address the misconceptions revealed during analysis and were implemented with flexibility to allow adjustments based on learner needs. Table 4 presents the suggested lesson structure, including objectives, materials, and duration.

Table 4. *Structure of the Lessons of the Learning Intervention Material*

Lesson Title	Objectives	Material	Duration (minutes)
Lesson 1: Differentiation and Reinforcement of Signs and Operations	Identify and distinguish positive and negative integers; reinforce understanding of signs and operations to reduce confusion.	COCO-Abacus, Interactive Workbook	45
Lesson 2: Introduction to the COCO-Abacus (Color Coded Abacus)	Familiarize learners with the COCO-Abacus and demonstrate how it represents positive and negative integers visually.	COCO-Abacus, Interactive Workbook	45
Lesson 3: Addition of Integers Using COCO-Abacus	Perform addition of integers using the COCO-Abacus; apply the Zero Pair concept for combining integers.	COCO-Abacus, Interactive Workbook	45

Lesson 4: Guided Discovery of the Rule in Adding Integers	Infer and articulate rules for adding integers through pattern recognition and guided activities.	Interactive Workbook	45
Lesson 5: Subtraction of Integers Using COCO-Abacus	Perform subtraction of integers using the COCO-Abacus; apply the Zero Pair concept for subtracting negatives.	COCO-Abacus, Interactive Workbook	45
Lesson 6: Guided Discovery of the Rule in Subtracting Integers	Discover and apply the "Keep, Change, Change" rule for subtraction through guided exercises.	Interactive Workbook	45
Lesson 7: Reinforcement Activities and Exercises	Apply rules for addition and subtraction of integers in real-life contexts (e.g., money, temperature).	Interactive Workbook	45

Development Phase

The development process involved drafting clear examples, creating diagrams of the COCO-Abacus, and designing workbook activities that encourage active participation. Each session was structured for approximately 45 minutes, combining teacher demonstrations, guided practice, and independent exercises. After drafting, the material underwent expert validation using DepEd LRMDS criteria to ensure content accuracy, clarity, and usability. Feedback from validators was incorporated into revisions, resulting in a resource that is pedagogically sound and appropriate for Grade 7 learners.

Alignment of Lesson Contents to Misconceptions

The design features—color coding, manipulative-based activities, guided discovery, and contextualized reinforcement—were selected to address specific misconceptions identified during analysis. Table 5 shows how each misconception aligns with the design feature and the corresponding lesson(s).

Table 5. *Alignment of Misconceptions with Design Features and Lessons*

Misconception	Design Feature	Lesson(s)
M1: Subtracting a negative is not converted to addition.	Use of the Zero Pair concept and the Keep-Change-Change rule to model subtraction as addition.	**Lesson 5**: Subtraction of Integers Using COCO-Abacus **Lesson 6**: Guided Discovery of the Rule in Subtracting Integers
M2: Incorrect sign choice when adding unlike signs.	Color coding for sign differentiation; Guided discovery to compare magnitudes and predict sign.	**Lesson 3**: Addition of Integers Using COCO-Abacus **Lesson 4**: Guided Discovery of the Rule in Adding Integers
M3: Assuming subtraction always gives a positive difference.	Contextualized examples (e.g., elevator ride, altitude changes) and visual representation on an abacus.	**Lesson 5**: Subtraction of Integers Using COCO-Abacus **Lesson 7**: Reinforcement Activities and Exercises
M4: Weak understanding of additive inverses (zero pairs).	Zero Pair Face-Off activity and visual pairing of beads to reinforce cancellation.	**Lesson 3**: Addition of Integers Using COCO-Abacus **Lesson 7**: Reinforcement Activities and Exercises
M5: Direction errors when subtracting a positive from a negative.	Step-by-step manipulative modeling and number-line analogy through contextual tasks.	**Lesson 5**: Subtraction of Integers Using COCO-Abacus **Lesson 7**: Reinforcement Activities and Exercises

The lesson structure and design features reflect research-based strategies for addressing misconceptions in integer operations. Visual aids, manipulative-based activities, and guided discovery tasks are consistent with recommendations from the National Council of Teachers of Mathematics (2000) and experiential learning theories (Piaget, 1973; Kolb, 1984), which advocate for hands-on, contextualized learning to strengthen conceptual understanding.

Validity of the Intervention Material

Table 6 presents descriptive statistics for expert ratings of the three evaluation factors: Content, Other Findings, and Manipulative Requirements. The mean scores are 39.60, 16.00, and 23.80, respectively, with standard deviations of 0.55, 0.00, and 0.45, and all factors received a "Passed" remark. These results indicate that the learning intervention material met or exceeded the DepEd LRMDS passing thresholds for validity. The high mean scores, particularly for Factor A (close to the maximum of 40), and the perfect score for Factor B, reflect excellent content quality and complete compliance with standards. The low standard deviations suggest strong consistency among validators, with Factor B showing absolute agreement (*SD* = 0.00). Collectively, these findings imply that experts unanimously consider the material accurate, relevant, and pedagogically sound, confirming its readiness for classroom implementation.

Table 6. *Descriptive Statistics of Expert Ratings per Factor*

Factor	Mean	SD	Remarks
Content	39.60	0.55	Passed
Other Findings	16.00	0.00	Passed
Manipulative Requirements	23.80	0.45	Passed

On the other hand, Table 7 shows that the Scale-Level Content Validity Index (*S-CVI/Ave*) for all three factors—Content, Other Findings, and Manipulative Requirements—along with the overall validity, is 1.00, which is interpreted as "Excellent Validity." These perfect scores indicate unanimous agreement among the five experts that every criterion in the evaluation tool is clear, relevant, and appropriate. The consistency of these ratings demonstrates that the material fully meets the standards for clarity, accuracy, and usability, confirming its readiness for classroom implementation.

Table 7. *Scale-Level Content Validity Index (S-CVI/Ave) per Factor*

Factor	S-CVI	Remarks
Content	1.00	Excellent Validity
Other Findings	1.00	Excellent Validity
Manipulative Requirements	1.00	Excellent Validity
Overall Validity	**1.00**	**Excellent Validity**

The validity is further supported by established benchmarks in content validation literature, which recommend an *S-CVI/Ave* of ≥ 0.90 for strong content validity (Polit & Beck, 2006). Since all factors achieved 1.00, the material exceeds these thresholds, reflecting exceptional quality and alignment with instructional standards. This result implies that the learning intervention material is not only pedagogically sound but also systematically designed to meet DepEd requirements, ensuring its effectiveness and appropriateness for Grade 7 learners.

Implementation and Evaluation

The final phase of the modified ADDIE process focused on determining the effectiveness and acceptability of the developed learning intervention material. After expert validation, the material was implemented with the selected Grade 7 learners following the structured lesson sequence. This stage involved administering a post-test to measure performance improvement compared to the pre-test, computing statistical significance and effect size, and evaluating learner perceptions using the Instructional Materials Motivation Survey (IMMS). The results from this phase provide evidence of the material's impact on conceptual understanding, procedural fluency, and motivational acceptability.

Level of Performance Before and After the Learning Intervention

The results in Table 8 indicate a significant improvement in learner performance from the Pre-Test to the Post-Test. The mean score increased from 10.68 (*SD* = 2.95) to 17.95 (*SD* = 2.77), reflecting a substantial gain of +7.27 points and a slight reduction in variability, suggesting more consistent outcomes across learners. In percentage terms, the Mean Percentage Score (MPS) rose from 53.41% to 89.77%, corresponding to a movement from the Beginning proficiency band to Advanced. Taken together, these shifts demonstrate pronounced improvement in central tendency and proficiency classification, indicating enhanced mastery of the assessed integer operations following the implementation period.

Table 8. *Descriptive Statistics of Pre-Test and Post-Test Scores and MPS*

Test	Mean	SD	MPS	Remarks
Pre-Test	10.68	2.95	53.41	Beginning
Post-Test	17.95	2.77	89.77	Advanced

Raw mean scores were used in the computation of descriptive and inferential statistics because statistical procedures such as the paired samples t-test and effect size computations are performed on raw values rather than on transmuted or grade-equivalent scores. Using raw scores ensures accurate measurement of changes in learners' performance between the pre-test and post-test. It maintains the integrity of the statistical assumptions required for repeated-measures analysis.

Subsequently, proficiency classifications based on transmuted scores are presented separately in Table 9 to describe performance levels. It shows a pronounced upward shift after the implementation. Before the intervention, 100.00% of learners were classified as Beginning (≤74%). After the intervention, the cohort was redistributed across higher levels: Advanced (≥90%) = 68.18%, Proficient (85–89%) = 4.55%, Approaching Proficiency (80–84%) = 9.09%, and Developing (75–79%) = 4.55%, with Beginning reduced to 13.64%. In a group of 22 learners, this corresponds to 15 Advanced, 1 Proficient, 2 Approaching Proficiency, 1 Developing, and 3 Beginning. This movement reflects not only statistical improvement but also substantial practical impact, as most learners progressed from limited foundational understanding to demonstrating strong mastery of integer rules. The large proportion who reached the Advanced proficiency level highlights their solid grasp of integer operations and shows clear gains in conceptual understanding and procedural fluency following the intervention.

Table 9. *Distribution of Learners by DepEd Proficiency Levels (Pre Test vs. Post Test)*

	Pre-Test		Post-Test	
Proficiency Level	**n**	**%**	**n**	**%**
Advanced (≥90%)	0	0.00	15	68.18
Proficient (85–89%)	0	0.00	1	4.55
Approaching Proficiency (80–84%)	0	0.00	2	9.09
Developing (75–79%)	0	0.00	1	4.55
Beginning (≤74%)	22	100	3	13.64
Total	**22**	**100**	**22**	**100**

These outcomes cohere with evidence that explicit, visualized practice and well-sequenced tasks help students resolve common misconceptions in signed-number reasoning and consolidate procedural fluency (Carbonneau et al., 2013). Integrating concrete/visual models with guided discovery and focused feedback is associated with larger gains and more homogeneous performance—patterns reflected here by the increased mean, reduced variability, and strong presence in the upper proficiency bands.

Difference in Level of Performance Before and After Implementation

Table 10. *Paired Samples t-Test Comparing Pre- and Post-Test Scores*

		Paired Differences						
Test	**Rating**	**Mean**	**SD**	**SE**	***t***	***df***	***p***	**Remarks**
Pre-Test Post Test	10.68 17.95	7.27	2.59	0.55	13.19	21	0.00	Significant

The paired differences between Pre-Test and Post-Test scores in Table 14 show a mean gain of 7.27 points with *SD* = 2.59 and *SE* = 0.55. The increase is statistically significant, $t(21) = 13.19$, $p < .001$, with a 95% confidence interval for the mean difference of [6.13, 8.42]. Normality of the difference scores was satisfied (Shapiro–Wilk $W = 0.94$, p = .16), supporting the use of the paired samples t-test. The post-test scores are reliably higher than the pre-test scores. Because the 95% CI for the mean difference does not include zero and the p-value is <.001, the observed gain is unlikely to be due to chance and indicates a substantial improvement in learner performance following the implementation period. This pattern is consistent with established guidance on analyzing repeated-measures data using paired t-tests, which recommends reporting the test statistic, degrees of freedom, p-value, and confidence interval to support transparent inference about change over time (Field, 2018; American Psychological Association, 2020).

Effect Size of the Intervention on Integer Operations

Table 11. *Effect Size of Pre-Test to Post-Test Improvement*

Test	Eta squared (η^2)	Remarks
Pre-Test Post Test	0.89	Large Effect

In table 11, the observed effect size for the pre–post difference, $\eta^2 = 0.89$ (i.e., approximately 89.23% of the variance in score gains attributable to the implementation period), denotes a very large magnitude when mapped to Cohen's d conventions (small ≈ 0.20, medium ≈ 0.50, large ≈ 0.80), and is consistent with what the literature predicts when instruction intentionally targets known integer misconceptions with structured, representation-rich methods. Meta-analytic and guidance reports show that explicit/structured components (e.g., worked examples, heuristics, guided practice) produce sizeable improvements in mathematics proficiency—particularly for learners who begin with weaker prior knowledge (Gersten et al., 2009). Complementary evidence from CRA (Concrete–Representational–Abstract) implementations suggests that transitioning from concrete manipulatives to visual/pictorial representations and then to symbolic procedures reduces error patterns and strengthens conceptual–procedural links, resulting in posttest advantages over traditional instruction (Witzel et al., 2003; Witzel et al., 2008). These findings provide a coherent theoretical and empirical basis for interpreting $\eta^2 = 0.89$ as not merely statistically large but educationally substantive, reflecting a cohort-wide movement from low to high mastery under instruction that integrates manipulatives/representations, explicit guidance, and comparison-based practice.

Table 12. *Item-Level Acceptability of the Learning Intervention*

Statement	Mean	SD	Remarks
Confidence			
When I first looked at the COCO-Abacus, I had the impression that it would be easy for me.	3.18	0.59	Acceptable
The COCO-Abacus was more difficult to understand than I would like it to be.	2.91	0.68	Acceptable
After reading the introductory information about the COCO-Abacus, I felt confident that I knew what I was supposed to learn.	4.09	0.87	Moderately Acceptable
Many aspects of using the COCO-Abacus had so much information that it was hard to pick out and remember the important points.	3.14	0.94	Acceptable
As I worked with the COCO-Abacus, I was confident that I could learn how to add and subtract integers.	4.32	1.04	Highly Acceptable
The COCO-Abacus exercises were too difficult.	2.32	1.13	Moderately Acceptable
After using the COCO-Abacus for a while, I was confident that I would be able to pass a test on adding and subtracting integers.	3.91	0.81	Moderately Acceptable
I could not quite understand how to use the COCO-Abacus.	2.32	0.84	Moderately Acceptable
The well-organized COCO-Abacus helped me feel confident that I would learn to add and subtract integers.	4.14	0.94	Moderately Acceptable
Attention			
There was something interesting at the beginning of the COCO-Abacus lesson that caught my attention.	3.59	1.05	Moderately Acceptable
The COCO-Abacus materials are eye-catching.	3.68	0.84	Moderately Acceptable
The quality of the explanations in the COCO-Abacus lessons helped to hold my attention.	3.55	0.86	Moderately Acceptable
The COCO-Abacus lessons are so abstract that it was hard to keep my attention.	2.77	0.75	Acceptable
The pages of the COCO-Abacus lessons look dry and unappealing.	1.68	0.72	Highly Acceptable
The way the information is arranged on the COCO-Abacus pages helped keep my attention.	3.55	0.67	Moderately Acceptable
The COCO-Abacus lessons have things that stimulate my curiosity.	3.86	0.83	Moderately Acceptable
The amount of repetition in the COCO-Abacus lessons caused me to get bored sometimes.	2.59	1.01	Moderately Acceptable
I learned some things that were surprising or unexpected from the COCO-Abacus lessons.	4.05	0.84	Moderately Acceptable
The variety of exercises and illustrations in the COCO-Abacus lessons helped keep my attention.	3.64	0.73	Moderately Acceptable
The writing style in the COCO-Abacus lessons is boring.	2.05	0.9	Moderately Acceptable
There are so many words on each page of the COCO-Abacus lessons that it is irritating.	2.23	1.02	Moderately Acceptable
Satisfaction			
Completing the exercises using the COCO-Abacus gave me a satisfying feeling of accomplishment.	3.77	1.02	Moderately Acceptable
I enjoyed the COCO-Abacus lessons so much that I would like to know more about this topic.	3.77	0.87	Moderately Acceptable
I really enjoyed studying the COCO-Abacus lessons.	3.82	1.1	Moderately Acceptable
The feedback after the exercises using the COCO-Abacus helped me feel rewarded for my effort.	4	0.98	Moderately Acceptable
It felt good to complete the COCO-Abacus lessons successfully.	4.05	0.84	Moderately Acceptable
It was a pleasure to work on such a well-designed learning tool as the COCO-Abacus.	3.77	1.07	Moderately Acceptable
Relevance			
It is clear to me how the content of the COCO-Abacus lessons relates to what I already know.	3.27	0.63	Acceptable
There were stories, pictures, or examples in the COCO-Abacus lessons that showed me how important this material could be to some people.	3.64	0.73	Moderately Acceptable
Completing the COCO-Abacus lessons successfully was important to me.	3.82	0.91	Moderately Acceptable
The content of the COCO-Abacus lessons is relevant to my interests.	3.41	1.01	Moderately Acceptable
There are explanations or examples of how people use the knowledge from the COCO-Abacus lessons.	3.77	0.81	Moderately Acceptable
The content and style of writing in the COCO-Abacus lessons convey the impression that its content is worth knowing.	3.27	0.88	Acceptable
The COCO-Abacus lessons were not relevant to my needs because I already knew most of them.	2.55	1.01	Moderately Acceptable
I could relate the content of the COCO-Abacus lessons to things I have seen, done, or thought about in my own life.	3.05	0.95	Acceptable
The content of the COCO-Abacus lessons will be useful to me.	4.5	0.74	Highly Acceptable

Level of Acceptability of the Learning Intervention

Learners' item-level ratings on the IMMS, as shown in Table 12, indicate that the learning intervention is generally well-received, with most positive statements falling in the Moderately Acceptable to Highly Acceptable range. Learners reported that the material "will be useful to me" (R9), $M = 4.50$, $SD = 0.74$, and that they were "confident [they] could learn how to add and subtract integers" (C5), $M = 4.32$, $SD = 1.04$, both mapping to favorable acceptability. In contrast, negatively worded items—interpreted with the rubric's negative column—show lower endorsement of unfavorable qualities: "pages look dry/unappealing" (A5), $M = 1.68$, $SD = 0.72$; "style of writing is boring" (A11), $M = 2.05$, $SD = 0.90$; "too many words; irritating" (A12), $M = 2.23$, $SD = 1.02$; "exercises too difficult" (C6), $M = 2.32$, $SD = 1.13$; and "could not really understand quite a bit" (C8), $M = 2.32$, $SD = 0.84$—each classed as Moderately Acceptable or better under the negative rubric, indicating that learners generally disagreed with these unfavorable statements. Taken together, the pattern shows strong perceived usefulness and learning confidence, with relatively low agreement on negative attributes, supporting an overall conclusion of moderate to high acceptability at the statement level.

Furthermore, learners' acceptability ratings on the IMMS, with negatively worded items reverse scored prior to aggregation, indicate moderate acceptability across dimensions: Attention ($M = 3.72$, $SD = 0.44$), Relevance ($M = 3.58$, $SD = 0.38$), Confidence ($M = 3.66$, $SD = 0.37$), and Satisfaction ($M = 3.86$, $SD = 0.67$). The Overall Acceptability mean was 3.69 ($SD = 0.36$). According to the study's rubric (3.41–4.20 = Moderately Acceptable), all dimension means fall within the Moderately Acceptable band, with Satisfaction rated highest and Relevance rated lowest, suggesting that learners perceived the material as engaging and rewarding, yet still moderately relevant and confidence-building. These results support an interpretation of consistent, favorable acceptability of the learning intervention across the IMMS motivational components.

Table 13. *Dimension-Level Acceptability of the Learning Intervention*

Dimension	Mean	SD	Remarks
Attention	3.72	0.44	Moderately Acceptable
Relevance	3.58	0.38	Moderately Acceptable
Confidence	3.66	0.37	Moderately Acceptable
Satisfaction	3.86	0.67	Moderately Acceptable
Overall Acceptability	**3.69**	**0.36**	**Moderately Acceptable**

Methodologically, the dimension results were computed after reverse-coding negative items, which aligns with current IMMS validation guidance, noting misfit/clustering for reverse-scored items and recommending careful handling before aggregation (Cook & Pankratz, 2024; Loorbach et al., 2014). Within the acceptability lens, the relatively higher Satisfaction mean coheres with design principles that emphasize clear feedback and a sense of accomplishment as drivers of positive user judgments, while Attention, Relevance, and Confidence in the Moderately Acceptable band suggest the material is generally perceived as engaging, useful, and navigable (Keller, 2010). These benchmarks substantiate the conclusion that learners accept the learning intervention as a usable, valuable resource—consistent with the observed profile of items and dimensions rated Moderately Acceptable to Highly Acceptable.

Conclusion

The findings demonstrate that Grade 7 learners initially exhibited widespread, concept-level difficulties in integer operations—particularly in transforming subtraction of negatives to addition, determining the correct sign when combining unlike signs, and reasoning about direction and magnitude on the number line. Patterns of errors indicated a reliance on rote rules rather than conceptual understanding, revealing the need for instruction that makes sign conventions, directionality, and zero pair reasoning explicit and tangible.

Guided by these insights, the learning intervention was designed around color-coded representations, manipulative-based modeling (using an abacus/zero pairs), and guided discovery of rules, with reinforcement through contextual tasks. Expert evaluation confirmed the material's clarity, coherence, and classroom suitability, and learners' post-implementation outcomes showed a consistent shift toward more accurate, rule-consistent solutions and more stable performance across the cohort. The overall profile of learner feedback further indicated that the material was perceived as engaging, useful, and navigable, with clear evidence that feedback-rich practice and structured sequencing supported a sense of accomplishment and confidence in learning. Collectively, the results substantiate that an intervention grounded in concrete representations, progressively linked to pictorial and symbolic reasoning, can correct persistent misconceptions, strengthen conceptual understanding, and translate into more proficient and confident performance in adding and subtracting integers.

The COCO-Abacus intervention effectively addressed prevalent misconceptions in integer operations and significantly improved learner performance, moving most students from the Beginning to the Advanced proficiency band. Its design features—color coding, manipulative modeling, guided discovery, and contextualized reinforcement—align with best practices in mathematics education and were validated as pedagogically sound and acceptable for classroom use. The strong validity ratings, significant pre–post gains, and very large effect size underscore the material's impact on conceptual understanding and procedural fluency. Learners' positive acceptability ratings further affirm its usability and perceived value.

Contributions of Authors

Author 1: conceptualization, data gathering, data analysis
Author 2: supervision, academic guidance, manuscript review

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