

Design and Validation of a Technology-Aided Interactive Mathematics Learning System for Primary Education [†]

Dana Kaye Fabiala ^{*}, Jhun August Mendez II, Maria Belinda Galivo, Shairane Potoy, Liza Melchor, Hannah Grace Fampulme and Mary Diane M. Mortel

Elementary Education Department, College of Education, Romblon State University, Odiongan 5505, Romblon, Philippines; jhunaugustmendez@gmail.com (J.A.M.II); mabelindagalivo19@gmail.com (M.B.G.); shairane4@gmail.com (S.P.); lizamelchor123@gmail.com (L.M.); hannahgracefampulme8@gmail.com (H.G.F.); marydianemortel@gmail.com (M.D.M.M.)

^{*} Correspondence: danakayefabiala@rsu.edu.ph; Tel.: +63-9504624819

[†] Presented at the 8th International Global Conference Series on ICT Integration in Technical Education & Smart Society, Aizuwakamatsu City, Japan, 20–26 January 2026.

Abstract

The increasing demand for technology-supported instructional solutions has created opportunities to develop learning systems that integrate curriculum alignment, instructional design, and learner-centered interaction within a unified educational framework. This study presents the design and validation of a Technology-Aided Interactive Mathematics Learning Framework that functions as an instructional support system for Grade 3 subtraction involving three- to four-digit numbers with and without regrouping. The proposed framework adopts the Four-D (4D) instructional development model as its system development methodology and incorporates structured content organization, interactive learning components, and curriculum-driven instructional configuration. A mixed-method developmental research approach was employed involving fourteen participants, including twelve Grade 3 teachers and two master teachers from public elementary schools in Alcantara, Romblon, Philippines. A needs assessment identified subtraction with regrouping as the highest-priority instructional challenge. The resulting instructional system was evaluated using the Department of Education Evaluation Rating Sheet for Print Resources and achieved an overall Very Satisfactory rating across content integrity, interface organization, presentation, instructional architecture, and information accuracy. Qualitative analysis further demonstrated that the framework supports curriculum alignment, contextual adaptability, learner engagement, and reusable instructional deployment while identifying opportunities for improving inclusivity and interface presentation. The findings demonstrate that the proposed technology-aided instructional framework provides a practical, scalable, and sustainable learning support configuration that can serve as a foundation for future intelligent educational systems, adaptive learning platforms, and digital instructional environments.



Academic Editors: Debopriyo Roy, George Fragulis and Peter Ilic

Published: 12 August 2026

Copyright: © 2026 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article distributed under the terms and conditions of the [Creative Commons Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.

Keywords: interactive learning framework; instructional support system; educational technology; learning system architecture; instructional configuration; curriculum-aligned framework; mathematics learning; technology-enhanced education

1. Introduction

Basic numeracy is a foundational life skill that enables learners to engage meaningfully in education, employment, and civic participation. Beyond school achievement, numer-

acy competence is strongly associated with improved life outcomes, including financial decision-making, employability, and socio-economic mobility [1,2]. However, when early mathematical difficulties remain unaddressed, they often evolve into cumulative learning gaps, negative academic self-concept, and persistent mathematics anxiety [3,4]. These early barriers are particularly consequential in primary education, where conceptual misunderstandings in number operations hinder progression toward more complex mathematical reasoning. Consequently, the development of sustainable, scaffolded, and developmentally appropriate instructional materials is not merely a pedagogical concern but a systemic imperative for building future-ready education systems.

Recent advances in educational technology have shifted instructional innovation from isolated learning resources toward integrated learning systems capable of supporting curriculum management, learner interaction, and instructional decision-making. Within computer science, educational systems are increasingly viewed as configurable software-assisted environments in which instructional components, learning activities, assessment mechanisms, and content organization operate as interconnected modules rather than standalone materials. Such technology-supported instructional frameworks improve consistency, scalability, maintainability, and reusability while enabling systematic deployment across diverse educational contexts.

Globally, concerns regarding foundational learning have intensified in recent years. The World Bank's 2022 update on learning poverty reports that a substantial proportion of children in low- and middle-income countries fail to achieve minimum proficiency in foundational skills, including numeracy [5]. The urgency of addressing early mathematics difficulties in the Philippines is underscored by large-scale international assessments. In the 2019 Trends in International Mathematics and Science Study (TIMSS), the Philippines ranked last among participating countries in Grade 4 mathematics, obtaining an average score of 297, far below the low international benchmark of 400 [6]. The most recent cycle, TIMSS 2023, continues to highlight wide global disparities in mathematics achievement across education systems and reinforces the importance of sustained monitoring of foundational competencies [6]. Similarly, in the Programme for International Student Assessment (PISA), Filipino 15-year-olds scored 353 in mathematics in 2018 compared to the OECD average of 489 [7], and although the 2022 cycle recorded a slight increase to 355, this performance remains significantly below the OECD average of 472, indicating persistent gaps in mathematical literacy [8]. Collectively, these findings signal systemic challenges in developing mathematical proficiency across grade levels and emphasize the need for early, targeted interventions at the primary stage.

Addressing persistent learning difficulties requires more than the production of instructional content. It requires the development of structured instructional support frameworks that organize learning resources through systematic architectures and predefined instructional workflows. Framework-oriented educational systems provide standardized mechanisms for integrating curriculum objectives, instructional sequencing, learner interaction, and evaluation processes into a unified configuration that can be replicated, validated, and continuously improved. Such approaches have become increasingly important in educational technology because they facilitate modular development while supporting future integration with intelligent tutoring systems, learning management systems, and adaptive learning platforms.

While international assessments quantify national learning gaps, classroom-level evidence offers more nuanced and actionable insights. Teachers' perceptions of Instructional difficulty often reveal misalignments between curriculum expectations and learners' developmental readiness [9–11]. Such perceptions are valuable indicators of where instructional scaffolds, material redesign, or pedagogical adjustments are most needed. Meta-analytic

evidence demonstrates that effective mathematics instruction in the elementary grades' benefits from structured guidance, visual supports, and opportunities for active manipulation of representations [12].

This pattern was evident in a needs-based assessment conducted across 12 public elementary schools in the Municipality of Alcantara, Romblon. Findings revealed that 83 percent of Grade 3 teachers identified subtraction involving three- to four-digit numbers, with and without regrouping, as the most difficult competency to teach. Teachers attributed this difficulty to learners' weak place-value understanding, limited problem-solving strategies, reduced attention span, and emerging mathematics anxiety. Respondents further emphasized that purely technology-based interventions, such as mobile applications and digital slides, did not consistently sustain engagement. Instead, pupils demonstrated stronger participation when tasks involved coloring, cutting, organizing, and physically manipulating materials. This observation aligns with Piaget's theory that learners in the concrete operational stage rely heavily on tangible experiences to internalize abstract concepts [13].

The proposed solution in this study can therefore be viewed as a technology-aided instructional support framework rather than merely a collection of printed worksheets. The framework consists of interconnected instructional components, including curriculum mapping, competency identification, structured activity sequencing, interactive learning modules, expert validation, and iterative refinement. These components collectively form a configurable instructional architecture that supports systematic content development while maintaining compatibility with existing educational standards. This system-oriented perspective aligns the work with computer science principles involving framework design, modular configuration, information organization, and educational system engineering.

The theoretical foundation of this study is anchored in Piaget's theory of cognitive development. Learners aged 7 to 11 operate within the concrete operational stage, characterized by logical reasoning grounded in observable and manipulable experiences [13]. Although children at this stage begin to understand conservation and reversibility, abstract symbolic manipulation such as multi-digit subtraction with regrouping still requires concrete scaffolding. Contemporary research supports this perspective, showing that structured manipulatives enhance conceptual understanding when carefully aligned with instructional goals [12,14]. Recent empirical work also indicates that interactive and guided activity sheets can significantly improve mathematical engagement and achievement among primary learners [15,16].

Beyond cognitive alignment, sustainability considerations further justify the design of low-tech instructional materials. Sustainable education frameworks emphasize resource efficiency, contextual responsiveness, and long-term usability in educational innovation [17]. In many public schools, especially in geographically isolated areas, reliable access to digital infrastructure remains inconsistent. Technology-aided design paired with low-technology implementation therefore offers a pragmatic solution. Materials can be digitally developed for precision and curriculum alignment yet reproduced as reusable, printable formats that reduce dependence on costly devices and continuous electricity consumption. Such an approach supports equitable access while maintaining environmental and economic sustainability.

Guided by these theoretical and empirical foundations, the present study proposes the development and validation of "Interactive Sheets," technology-aided and curriculum-aligned instructional materials designed to support Grade 3 subtraction competencies. While digitally structured for precision and standard alignment, the materials are implemented as physical, manipulable sheets incorporating coloring, cutting, and pasting tasks. This dual-mode design bridges technological efficiency and tactile engagement,

supporting both cognitive development and sustainable classroom practice. To ensure quality and alignment, the materials underwent expert validation by two master teachers using four evaluative criteria: content accuracy, format and visual design, presentation and organization, and alignment with the Department of Education's Most Essential Learning Competencies [18]. Feedback from 12 Grade 3 mathematics teachers informed iterative revisions to refine layout clarity, contextual examples, and instructional sequencing.

Unlike conventional instructional material development studies, the present research emphasizes the design and validation of an instructional framework that formalizes the relationships among curriculum standards, learning activities, learner interaction, and expert evaluation. The framework establishes a repeatable development configuration capable of supporting future software implementation, digital learning environments, and intelligent instructional services. Consequently, the contribution of this research extends beyond educational resource development by proposing a structured instructional system architecture that can serve as a foundational model for subsequent computer-based educational applications.

Ultimately, guided by these theoretical and empirical foundations, the present study proposes the development and validation of a Technology-Aided Interactive Mathematics Learning Framework, in which the interactive sheets constitute the primary instructional modules of an integrated instructional support system. By integrating developmental theory, teacher-informed design, and sustainability principles, this study contributes to the discourse on instructional material innovation in basic education and establishes a foundation for future quasi-experimental classroom implementation. More broadly, it demonstrates how low-cost, context-sensitive, and human-centered instructional materials can serve as viable interventions for strengthening foundational numeracy in resource-constrained settings.

2. Theoretical Framework

This study is grounded in constructivist learning theory, particularly Jean Piaget's theory of cognitive development, and in systematic instructional design theory through the 4D model of Thiagarajan, Semmel, and Semmel. Together, these frameworks provide the cognitive and procedural foundations for the development and validation of the Interactive Sheets.

2.1. *Theory of Cognitive Development*

Piaget's Theory of Cognitive Development provides a foundational explanation of how children construct knowledge through active engagement with their environment [13]. According to Piaget, learners between the ages of 7 and 11 operate within the concrete operational stage, during which logical reasoning begins to develop but remains closely tied to tangible and manipulable experiences. At this stage, children acquire abilities such as conservation, classification, and reversibility; however, abstract symbolic reasoning, including multi-digit subtraction with regrouping, still requires concrete scaffolding [13].

Contemporary research continues to affirm the relevance of Piagetian principles in mathematics education. A meta-analysis examining the use of concrete manipulatives in mathematics instruction found that manipulatives significantly enhance conceptual understanding when integrated with structured guidance and explicit instructional goals [12]. This finding aligns with constructivist assumptions that learning occurs most effectively when learners actively construct meaning rather than passively receive information. Furthermore, research in embodied cognition demonstrates that physical interaction with learning materials strengthens cognitive processing by linking motor actions to abstract reasoning [19]. Such evidence supports Piaget's concepts of assimilation and accommo-

dation, in which learners integrate new mathematical knowledge into existing cognitive structures and modify those structures through meaningful engagement [13].

In Grade 3 mathematics, subtraction with and without regrouping requires understanding place value relationships, number decomposition, and operational reversibility. These competencies are developmentally appropriate within the concrete operational stage but demand structured experiences that render abstract numerical operations visible and manipulable. Recent empirical studies indicate that interactive and guided worksheets improve learners' mathematical engagement, retention, and reasoning when they incorporate visual and tactile elements [20,21]. By integrating coloring, cutting, pasting, and structured problem-solving tasks, the Interactive Sheets operationalize Piagetian principles, enabling pupils to manipulate representations of numerical relationships physically and thereby strengthening conceptual understanding while reducing mathematics anxiety.

2.2. 4D Instructional Design Model

Complementing the cognitive foundation of this study is the 4D model of instructional development proposed by Thiagarajan, Semmel, and Semmel [22]. The 4D Model (Define, Design, Develop, and Disseminate) offers a systematic framework for creating instructional materials that are responsive to learner needs and grounded in empirical validation.

The Define phase emphasizes needs assessment and identification of learning gaps. In this study, teacher-reported difficulties in multi-digit subtraction informed the prioritization of instructional objectives. The design phase translates identified needs into structured content, activity sequencing, and assessment strategies aligned with curriculum standards. The development phase involves prototyping, expert validation, and iterative refinement to ensure content accuracy, clarity, and usability. Finally, the dissemination phase focuses on implementation, feedback collection, and evaluation of instructional effectiveness.

Recent research in instructional design underscores the continued relevance of systematic development models in producing high-quality, learner-centered materials. Instructional materials developed using systematic instructional design frameworks tend to enhance learning outcomes because these models guide the alignment of learning tasks, feedback, and instructional strategies with targeted competencies [23,24]. In mathematics education specifically, research indicates that instructional materials developed through systematic design models are more effective in addressing identified competency gaps compared to textbook-dependent approaches [25,26].

By applying the 4D model, this study ensures that the interactive sheets are not only theoretically grounded but also systematically developed, validated, and refined based on expert and practitioner feedback. The integration of constructivist cognitive theory with a structured instructional design model strengthens both the pedagogical rationale and methodological rigor of the study.

2.3. Integrative Theoretical Position

The theoretical framework of this research rests on two complementary foundations. Constructivist developmental theory explains how learners internalize mathematical concepts through active, concrete engagement. Systematic instructional design theory ensures that materials are intentionally engineered, validated, and aligned with curriculum standards. Together, these perspectives justify the development of technology-aided yet low-technology interactive sheets as developmentally appropriate, sustainable, and empirically supported instructional tools for strengthening foundational numeracy among Grade 3 learners.

3. Methods

3.1. Research Design

This study employed a mixed-methods research design integrating quantitative and qualitative approaches to provide a comprehensive evaluation of the developed instructional materials. Mixed-methods research enables the integration of numerical trends with contextual explanations, thereby strengthening validity through methodological triangulation [27]. The quantitative component focused on descriptive statistical analysis of survey and validation data, while the qualitative component involved thematic analysis of evaluator feedback.

The study specifically adopted a developmental research design. Developmental research is appropriate when the primary objective is the systematic design, validation, and refinement of educational products grounded in empirical evidence [28]. This approach ensures that instructional materials are not only theoretically informed but also iteratively improved through expert evaluation and contextual feedback.

3.2. Developmental Research Design

The development of the interactive sheets followed the Four-D Instructional Design Model proposed by Thiagarajan, Semmel, and Semmel [20], which consists of four sequential phases: Define, Design, Develop, and Disseminate.

In the Define phase, a needs assessment survey was administered to Grade 3 mathematics teachers to identify the least mastered essential learning competency. Survey findings indicated that subtraction involving three- to four-digit numbers, with and without regrouping, was perceived as the most difficult competency to teach. This phase established the instructional focus of the material.

In the design phase, the content structure, task sequencing, layout, and activity components of the interactive sheets were conceptualized. All content was aligned with the Grade 3 Mathematics Most Essential Learning Competencies to ensure curricular coherence and instructional relevance.

During the Develop phase, the Interactive Sheets were produced using digital design tools. Each sheet incorporated guided instructions, structured practice sections, and interactive elements such as cut-and-paste visuals to promote active learner engagement. The draft materials underwent expert validation using the Department of Education's Evaluation Rating Sheets for Print Resources. Feedback from validators informed revisions related to clarity, formatting, presentation, and instructional flow.

In the dissemination phase, the revised materials were shared with participating teachers for final review and documentation. Although large-scale classroom implementation was beyond the scope of this study, the dissemination process ensured that the materials were accessible to teachers within the district and ready for future pilot testing and broader utilization.

This integrated developmental process ensured that the instructional materials were systematically designed, empirically validated, and contextually responsive to classroom needs.

3.3. Research Locale and Duration

The study was conducted in the Municipality of Alcantara, located in the Province of Romblon, Philippines, under the Schools Division of Romblon. The district consists of 12 public elementary schools serving diverse learner populations.

Data collection, instructional design, validation, and revision were conducted during school year 2024 to 2025. This duration provided sufficient time for implementing all

four phases of the developmental process, including needs assessment, material development, expert validation, and revision.

3.4. Participants

The study utilized complete enumeration sampling, in which all eligible Grade 3 mathematics teachers and master teachers within the district were invited to participate. Complete enumeration is appropriate when the population size is manageable and when the study seeks comprehensive representation of a defined group [27].

A total of 14 participants were included in the study, consisting of 12 Grade 3 mathematics teachers and two master teachers. Eligibility required a minimum of two years of experience teaching Grade 3 mathematics to ensure familiarity with curriculum standards and instructional challenges. The same 14 participants served as validators of the developed instructional materials. Their professional classifications included two master teachers, six Teacher III, three Teacher II, and three Teacher I. Teaching experience ranged from 2 to 31 years, with an average of approximately 16.8 years. The breadth of experience and professional ranks enhanced the credibility and contextual relevance of the evaluation process.

3.5. Data Collection Instruments and Procedures

Two primary instruments were utilized in this study.

First, a researcher-developed survey questionnaire was administered to identify the least mastered essential learning competency in Grade 3 mathematics. The instrument required teachers to rate the perceived difficulty of competencies aligned with the Most Essential Learning Competencies. The results informed the content focus of the Interactive Sheets and ensured that the material addressed authentic classroom learning gaps.

Second, the developed instructional materials were evaluated using the Department of Education's standardized Evaluation Rating Sheets for Print Resources under the Learning Resources Management and Development System. The instrument assesses instructional materials across dimensions such as content accuracy, format and visual design, presentation and organization, and relevance of information. Validators provided quantitative ratings and qualitative written feedback. The inclusion of both rating scales and open-ended responses strengthened the evaluation process by capturing measurable assessments alongside professional insights.

3.6. Data Analysis

Quantitative data from the survey and validation ratings were analyzed using descriptive statistics. The mean was computed to determine the average difficulty rating of competencies and the overall evaluation scores of the instructional materials. The standard deviation was calculated to assess variability and determine the degree of agreement among validators.

Qualitative data from written feedback were analyzed using thematic analysis. Responses were coded, categorized, and synthesized to identify recurring patterns and recommendations. Thematic analysis allows systematic identification of themes within qualitative data while maintaining analytic rigor [29].

All procedures adhered to the quality assurance standards outlined in the Learning Resources Management and Development System of the Department of Education to ensure that the instructional materials met established criteria for educational print resources [30].

4. Results

4.1. Identification of the Most Difficult Competency

The baseline survey revealed that most Grade 3 mathematics competencies were rated within the “Easy” range ($M = 1.42$ – 2.58). However, subtraction involving 3- to 4-digit numbers with and without regrouping was rated “Difficult” ($M = 3.17$, $SD = 0.72$). A total of 83% of teachers identified this competency as the most difficult to teach (Table 1).

Table 1. Most Difficult Competency Identified by Teachers.

Competency	Mean	SD	Interpretation	% Identifying as Most Difficult
Subtracts 3- to 4-digit numbers with and without regrouping	3.17	0.72	Difficult	83%

4.2. Expert Evaluation of the Interactive Sheets

The interactive sheets were evaluated by experts in terms of content, instructional design, and other established criteria for instructional materials. Overall, the materials received very satisfactory ratings across the evaluation criteria. The detailed evaluation results are presented in the succeeding subsections.

4.2.1. Content

The interactive sheets obtained an overall mean rating of 3.73 ($SD = 0.56$), interpreted as Very Satisfactory. The highest mean ratings ($M = 3.86$) were recorded for curriculum alignment and absence of bias. The lowest mean rating ($M = 3.36$, $SD = 1.45$) was observed for enhancement of values and traits (Table 2).

Table 2. Expert Evaluation in Terms of Content.

Evaluation Criteria	Mean	SD	Interpretation
Developmentally appropriate	3.79	0.43	Very Satisfactory
Curriculum alignment	3.86	0.36	Very Satisfactory
Higher-order thinking skills	3.79	0.43	Very Satisfactory
Free from bias	3.86	0.36	Very Satisfactory
Enhances values and traits	3.36	1.45	Very Satisfactory
Arouses learner interest	3.79	0.43	Very Satisfactory
Provides safety notes	3.71	0.47	Very Satisfactory
Overall	3.73	0.56	Very Satisfactory

4.2.2. Format

The overall mean for format was 3.79 ($SD = 0.40$), indicating a Very Satisfactory rating. Among components, Size and Weight of Resource obtained the highest sub-mean ($M = 3.93$), while Design and Layout had the lowest sub-mean ($M = 3.70$) (Table 3).

Table 3. Expert Evaluation in Terms of Format.

Component	Mean	SD	Interpretation
Prints	3.79	0.41	Very Satisfactory
Illustrations	3.73	0.45	Very Satisfactory
Design and Layout	3.70	0.48	Very Satisfactory
Paper and Binding	3.82	0.39	Very Satisfactory
Size and Weight	3.93	0.27	Very Satisfactory
Overall	3.79	0.40	Very Satisfactory

4.2.3. Presentation and Organization

The overall mean score for presentation and organization was 3.80 (SD = 0.40), corresponding to Very Satisfactory. Logical flow of ideas received the highest rating (M = 3.93), while vocabulary appropriateness received the lowest rating (M = 3.71) (Table 4).

Table 4. Expert Evaluation in Terms of Presentation and Organization.

Component	Mean	SD	Interpretation
Engaging presentation	3.79	0.43	Very Satisfactory
Logical flow of ideas	3.93	0.27	Very Satisfactory
Appropriate vocabulary	3.71	0.47	Very Satisfactory
Sentence length suitability	3.79	0.43	Very Satisfactory
Varied sentence structure	3.79	0.43	Very Satisfactory
Overall	3.80	0.40	Very Satisfactory

4.2.4. Accuracy and Up-to-Datedness

The materials achieved an overall mean of 3.81 (SD = 0.39), interpreted as Not Present for all identified errors. Conceptual errors received the highest mean (M = 3.93), while computational errors and obsolete information received the lowest means (M = 3.71) (Table 5).

Table 5. Expert Evaluation in Terms of Accuracy and Up-to-datedness.

Component	Mean	SD	Interpretation
Conceptual errors	3.93	0.27	Not Present
Factual errors	3.86	0.36	Not Present
Grammatical errors	3.79	0.43	Not Present
Computational errors	3.71	0.47	Not Present
Obsolete information	3.71	0.47	Not Present
Typographical errors	3.86	0.36	Not Present
Overall	3.81	0.39	Not Present

4.3. Thematic Analysis of Expert Feedback

Thematic analysis of expert feedback identified three themes highlighting the strengths of the instructional materials: Content Relevance and Usefulness, Design and Practical Features, and Engagement and Creativity (Table 6). Experts noted that the materials effectively support the learning needs of Grade 3 pupils and can be utilized by both teachers and learners. The comments also emphasized the visual appeal and portability of the materials, indicating their practicality for classroom and home use. Additionally, experts highlighted that the activities are engaging and original, suggesting their potential to motivate learners during instruction.

Table 6. Thematic Analysis of Expert Comments on the Interactive Math Sheets.

Theme	Frequency	Extracted Statements
Content Relevance and Usefulness	2	“Effectively supports the learning needs of Grade 3 pupils”; “Can be used by both teachers and pupils.”
Design and Practical Features	2	“Visually appealing” and “convenient for pupils to bring at home and school.”
Engagement and Creativity	2	“Encourages engagement while learning”; “Activities are original and unique.”

Expert suggestions for improvement were grouped into three themes: Inclusive and Culturally Relevant Design, Values Integration in Content, and Visual and Formatting Preferences (Table 7). Most suggestions focused on improving inclusivity and formatting elements, such as adding culturally familiar examples, simplifying language, adjusting font style and size, and modifying illustrations. Some experts also recommended integrating values in word problems and organizing tasks progressively from easy to difficult.

Table 7. Thematic Analysis of Expert Recommendations on the Interactive Math Sheets.

Theme	Frequency	Extracted Statements
Inclusive and Culturally Relevant Design	4	"Feature a female student on the cover page." "Use local fruits like mangga, guava, and calamansi." "Use simpler words." "Use clear number sentences."
Values Integration in Content	2	"Word problems should reflect positive traits such as helpfulness"; "Activities should progress from easy to difficult."
Visual and Formatting Preferences	4	"Replace the basket with a nest and the circle with an egg." "Use font size 14." "Use Century Gothic or Comic Sans." "Scramble the choices."

5. Discussion

The findings indicate that multi-digit subtraction with regrouping remains a significant instructional challenge in Grade 3 mathematics. The large proportion of teachers (83%) identifying this competency as difficult suggests that the issue is not isolated but rather reflects a broader instructional concern. The strong validation results of the material also indicate that the materials are well aligned with curricular objectives and pedagogical standards. Experts rated the content, format, and organization as very satisfactory, suggesting that the materials effectively support instructional delivery. Structured and well-sequenced instructional materials have been shown to enhance mathematics learning by scaffolding cognitive processes and reducing learner confusion [31,32]. When learning materials present concepts in a clear and logical sequence, students are better able to integrate conceptual knowledge with procedural steps.

The high ratings for format and usability also highlight the importance of visual clarity and accessible design in instructional materials. Research in cognitive load theory suggests that well-organized visual layouts and readable formats help reduce extraneous cognitive load, allowing learners to focus on understanding mathematical concepts rather than decoding instructional materials [33]. In elementary mathematics instruction, visual supports and simplified representations have been found to improve comprehension and reduce computational errors [34].

Although the indicator related to values integration received slightly lower ratings, it remained within the Very Satisfactory category. This finding suggests that while the instructional materials effectively address cognitive learning outcomes, there may be opportunities to strengthen the integration of character-building components. Recent studies emphasize that embedding contextualized and values-oriented tasks in instructional materials can enhance both cognitive engagement and socio-emotional development among learners. A systematic review of contextualized instructional materials in Philippine education reported that lessons aligned with learners' cultural backgrounds, local contexts, and real-life experiences significantly improve knowledge acquisition, comprehension,

participation, and academic performance, while also promoting stronger motivation and long-term knowledge retention [35].

The qualitative feedback further supports the quantitative findings by highlighting the importance of inclusivity, cultural relevance, and learner-centered design. Experts recommended incorporating culturally familiar contexts and inclusive representations in the materials. Previous studies indicate that culturally responsive instructional materials increase learner motivation and improve conceptual understanding by connecting concepts to students' everyday experiences [36,37].

Overall, the convergence of baseline survey results and expert validation demonstrates that the developed interactive sheets address a clearly identified instructional need. By focusing on a difficult competency and applying evidence-based instructional design principles, the materials show strong potential to support teachers and improve learner performance in subtraction with regrouping.

6. Conclusions

This study developed and validated technology-aided interactive sheets designed to support the teaching of subtraction involving three- to four-digit numbers with and without regrouping in Grade 3 mathematics. Findings revealed that this competency remains a significant instructional challenge, with the majority of teachers identifying it as the most difficult concept to teach, largely due to learners' limited conceptual understanding of place value and reliance on procedural strategies. The developed instructional materials received high validation ratings across content accuracy, format and visual design, presentation and organization, and accuracy of information, indicating that the Interactive Sheets are developmentally appropriate, curriculum-aligned, and pedagogically sound for classroom use. Expert feedback further emphasized the materials' practicality, visual appeal, and potential to increase learner engagement through interactive activities such as coloring, cutting, and organizing numerical representations. Grounded in constructivist learning theory and systematically developed through the 4D instructional design model, the materials demonstrate how structured and developmentally responsive instructional resources can address identified competency gaps in elementary mathematics. Moreover, the combination of technology-aided design and low-technology classroom implementation offers a sustainable and scalable approach to instructional material development, particularly in resource-constrained educational contexts. Overall, the study highlights the potential of systematically designed instructional materials to support teachers, enhance learner engagement, and strengthen foundational numeracy in primary education, while providing a foundation for future research examining their effectiveness through classroom-based implementation.

Author Contributions: Conceptualization, D.K.F., J.A.M.II, M.B.G., S.P., L.M., H.G.F. and M.D.M.M.; methodology, D.K.F., J.A.M.II, M.B.G., S.P., L.M., H.G.F. and M.D.M.M.; validation, J.A.M.II, M.B.G., S.P., L.M., H.G.F. and M.D.M.M.; formal analysis, J.A.M.II, M.B.G. and S.P.; writing—original draft preparation, J.A.M.II, M.B.G. and S.P.; writing—review and editing, D.K.F.; supervision, D.K.F. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: This study was conducted in accordance with institutional research guidelines and ethical standards. Before data collection, the researchers obtained approval from CED. Informed consent was secured from the participant involved in the process walkthrough, including consent for observation, interviews, and the use of operational insights for academic reporting. Participation was voluntary, and the right to withdraw or withhold information was

respected throughout the study. All data collected were treated with strict confidentiality and used solely for academic and institutional development purposes. No personally identifiable or sensitive financial information was disclosed in the reporting of results. The study adhered to ethical principles of transparency, respect, and integrity in conducting research involving human participants.

Data Availability Statement: The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

Acknowledgments: The authors express their sincere gratitude to the Grade 3 Mathematics teachers who participated in the baseline survey and shared valuable insights regarding the most challenging competencies in mathematics instruction. The authors also extend their appreciation to the expert validators for their time, expertise, and constructive feedback in evaluating the developed interactive math sheets. Their insights greatly contributed to improving the quality and clarity of the instructional materials. Appreciation is likewise extended to the school administrators for their support and cooperation during the data collection process. Finally, the authors acknowledge the assistance of the student researchers who contributed to the development of the instructional materials and the preparation of research data. While preparing this work, the authors employed ChatGPT Plus (GPT-5.2, developed by OpenAI) to assist with drafting, refining, and organizing sections of the manuscript, including the articulation of findings, development of technical narratives, and formatting of academic components such as methods, discussion, and acknowledgments. Following its use, the authors thoroughly reviewed and edited all AI-assisted content and assume full responsibility for the accuracy, integrity, and originality of the final manuscript.

Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

CED	RSU-College of Education
DepEd	Department of Education
IM	Instructional Material
LRMDS	Learning Resources Management and Development Systems
MELCs	Most Essential Learning Competencies
OECD	Organization for Economic Co-operation and Development
PISA	Programme for International Student Assessment

References

1. OECD. *PISA 2018 Results (Volume I): What Students Know and Can Do*; OECD Publishing: Paris, France, 2019. [CrossRef]
2. World Bank. *World Development Report 2018: Learning to Realize Education's Promise*; World Bank: Washington, DC, USA, 2018. [CrossRef]
3. Powell, S.R.; Fuchs, L.S. Early Numerical Competencies and Students with Mathematics Difficulty. *Focus Except. Child.* **2012**, *44*, 1–16. [CrossRef] [PubMed Central]
4. Cohen, L.D.; Korem, N.; Rubinsten, O. Math anxiety is related to math difficulties and composed of emotion regulation and anxiety predisposition: A network analysis study. *Brain Sci.* **2021**, *11*, 1609. [CrossRef] [PubMed]
5. World Bank. The State of Global Learning Poverty: 2022 Update. 2022. Available online: <https://www.worldbank.org/en/topic/education/publication/state-of-global-learning-poverty> (accessed on 12 March 2025).
6. IEA. TIMSS 2019 International Results in Mathematics and Science. 2020. Available online: <https://www.iea.nl/publications/study-reports/timss-2019-international-results> (accessed on 30 March 2025).
7. Department of Education, Republic of the Philippines. PISA 2018 Philippine National Report. 2019. Available online: <https://www.deped.gov.ph/wp-content/uploads/2019/12/PISA-2018-Philippine-National-Report.pdf> (accessed on 15 March 2024).
8. OECD. *PISA 2022 Results (Volume I): The State of Learning and Equity in Education*; OECD Publishing: Paris, France, 2023. [CrossRef]
9. Karali, Y. Difficulties Classroom Teachers encounter in Teaching Mathematics: A Phenomenological study. *Int. J. Progress. Educ.* **2022**, *18*, 75–99. [CrossRef]

10. Hunt, J.; Taub, M.; Duarte, A.; Bentley, B.; Womack-Adams, K.; Marino, M.; Holman, K.; Kuhlman, A. Elementary Teachers' perceptions and enactment of Supplemental, Game-Enhanced Fraction Intervention. *Educ. Sci.* **2023**, *13*, 1071. [CrossRef]
11. Hindi, A.N.A.; Muthahharah, I. Teacher's perception of student's mathematics learning difficulties. *Daya Mat. J. Inov. Pendidik. Mat.* **2021**, *9*, 171. [CrossRef]
12. Carbonneau, K.J.; Marley, S.C.; Selig, J.P. A meta-analysis of the efficacy of teaching mathematics with concrete manipulatives. *J. Educ. Psychol.* **2012**, *105*, 380–400. [CrossRef]
13. Piaget, J. *The Origins of Intelligence in Children*; W W Norton & Co eBooks: New York, NY, USA, 1952. [CrossRef]
14. Ochugboju, A.O.; Diez-Palomar, J. Systematic review on the use of virtual and physical manipulatives by primary school teachers. *Soc. Sci. Humanit. Open* **2025**, *12*, 102188. [CrossRef]
15. Widodo, S.A.; Hidayat, W.; Ekawati, R.; Irfan, M.; Maarif, S. The importance of creating mathematical worksheets and their impact on critical and creative thinking skills. *Eur. J. STEM Educ.* **2025**, *10*, 31. [CrossRef] [PubMed]
16. Felix, F.; Balingway, R. Effectiveness of Contextualized Worksheet in Improving Mathematics Performance of Grade IV Learners. 2025. Available online: <https://ejournals.ph/article.php?id=30781> (accessed on 15 December 2025).
17. Jäggle, G.; Posekany, A.; Lepuschitz, W.; Koppensteiner, G.; Zakall, S.; Vincze, M.; Merdan, M. Educational practices for improvement of sustainability education at secondary school level. *Sci. Act.* **2024**, *61*, 207–216. [CrossRef]
18. Department of Education, Republic of the Philippines. Most Essential Learning Competencies (MELCs). 2020. Available online: <https://www.deped.gov.ph/2020/07/13/melcs/> (accessed on 15 March 2025).
19. Novack, M.A.; Congdon, E.L.; Hemani-Lopez, N.; Goldin-Meadow, S. From action to abstraction. *Psychol. Sci.* **2014**, *25*, 903–910. [CrossRef] [PubMed]
20. Hetmanenko, L. The role of interactive learning in mathematics education: Fostering student engagement and interest. *Multidiscip. Sci. J.* **2024**, *6*, 2024ss0733. [CrossRef]
21. Daodao, J.C. Harnessing tactile learning to enhance mathematics achievement: A hands-on approach review. *Cogniz. J. Multidiscip. Stud.* **2025**, *5*, 321–331. [CrossRef]
22. Thiagarajan, S.; Semmel, D.S.; Semmel, M.I. *Instructional Development for Training Teachers of Exceptional Children: A Sourcebook*; (Report No. ED090725); Indiana University, ERIC: Bloomington, IN, USA, 1974. Available online: <https://eric.ed.gov/?id=ED090725> (accessed on 20 August 2024).
23. Weng, X.; Chiu, T.K. Instructional design and learning outcomes of intelligent computer assisted language learning: Systematic review in the field. *Comput. Educ. Artif. Intell.* **2023**, *4*, 100117. [CrossRef]
24. Abuhassna, H.; Adnan, M.A.B.M.; Awae, F. Exploring the synergy between instructional design models and learning theories: A systematic literature review. *Contemp. Educ. Technol.* **2024**, *16*, ep499. [CrossRef] [PubMed]
25. Putra, F.H.K.; Taufik, M.; Nadlifah, M. Development of MATLAB GUI-Based Mathematics Learning Media with ADDIE Model to Enhance Students' Mathematical Connection Ability. *Math. Educ. J.* **2024**, *8*, 102–113. [CrossRef]
26. Widyastuti, E.; Susiana. Using the ADDIE model to develop learning material for actuarial mathematics. *J. Phys. Conf. Ser.* **2019**, *1188*, 012052. [CrossRef]
27. Creswell, J.W.; Creswell, J.D. *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*, 5th ed.; Sage Publications: Thousand Oaks, CA, USA, 2018.
28. Richey, R.C. Developmental Research: The Definition and Scope. Available online: <https://eric.ed.gov/?id=ED373753> (accessed on 20 August 2024).
29. Braun, V.; Clarke, V. Using thematic analysis in psychology. *Qual. Res. Psychol.* **2006**, *3*, 77–101. [CrossRef]
30. Department of Education. *Guidelines and Processes for LRMDs Assessment & Evaluation (Final Draft 1.0)*; Department of Education: Pasig City, Philippines, 2009. Available online: <https://lrmds.deped.gov.ph/docs/LRMDSGuidelines.pdf> (accessed on 21 August 2024).
31. Ablir, J.B. Instructional material for enhancing learners' mathematics proficiency. *Int. J. Res. Publ.* **2023**, *124*, 725–736. [CrossRef]
32. Etcuban, J.O.; Capuno, R.; Revalde, H.; Aventuna, M.; Medio, G.; Demeterio, R.A. Facilitating learning mathematics through the use of instructional media. *Int. Electron. J. Math. Educ.* **2019**, *15*, 677–688. [CrossRef] [PubMed]
33. Schoenherr, J.; Strohmaier, A.R.; Schukajlow, S. Learning with visualizations helps: A meta-analysis of visualization interventions in mathematics education. *Educ. Res. Rev.* **2024**, *45*, 100639. [CrossRef]
34. Barbieri, C.A.; Rodrigues, J. Leveraging cognitive load theory to support students with mathematics difficulty. *Educ. Psychol.* **2025**, *60*, 208–232. [CrossRef]
35. Dohinog, J.; Aniñon, C.; Gornez, I.; Pagador, A.F.; Garupa, M.J.; Pocong, G.M.; Bolo, C.C.; Deniega, L.M.; Sitones, J.; Ducanes, R.J.; et al. Utilization of Contextualized Instructional materials in Education: A Systematic review. *Psychol. Educ. A Multidiscip. J.* **2025**, *44*, 203–214. [CrossRef]

36. Lovido, J.A.; Salazar, D.A. Culturally Responsive Teaching (CRT): Effects on students' academic performance and science process skills in chemistry. *Int. J. Res. Interdiscip. Stud.* **2026**, *4*, 6–12. [[CrossRef](#)]
37. Harahap, Y.S.; Ramadhani, R.; Sirait, D.; Siregar, N. *Project-Based Learning Through a Culturally Responsive Lens: Enhancing Learners' English Literacy Skills*; Zenodo (CERN European Organization for Nuclear Research): Geneva, Switzerland, 2025. [[CrossRef](#)]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.