

## Developing Student Worksheets Based on Hierarchical Organization of Mathematical Content to Support Numeracy Learning in Primary Schools

Hikmah Ramdhani Putri<sup>1,\*</sup>, Lalu Hamdian Affandi<sup>1</sup>, Baiq Yuni Wahyuningsih<sup>1</sup>, Iva Nurmawanti<sup>1</sup>, Vivi Rachmatul Hidayati<sup>1</sup>, and Nur Imama<sup>1</sup>

<sup>1</sup> Department of Elementary Teacher Education, Faculty of Teacher Training and Education, University of Mataram, Mataram, Indonesia

Email: hikmah.ramdhaniputri@unram.ac.id (H.R.P); hamdian.fkip@unram.ac.id (L.H.A); baiqyuniwahyu27@staff.unram.ac.id (B.Y.W); ivanurmawanti@unram.ac.id (I.N); vivirachma@unram.ac.id (V.R.H); nurimama@student.unram.ac.id (N.I)

\*Corresponding author

**Abstract**—Numeracy is an important foundation for students' subsequent mathematical learning. This study aimed to develop student worksheets based on the hierarchical organization of mathematical content to support numeracy learning in Phase A primary school. The worksheets were developed using the 4-D model, consisting of Define, Design, Develop, and Disseminate stages. The developed product consisted of seven student worksheets covering number representation, place value, comparison and ordering of numbers, addition, subtraction, basic fractions, and non-number patterns. The validity of the worksheets was evaluated by six validators, consisting of four university lecturers and two elementary school teachers. Data were collected using a validation questionnaire consisting of 25 indicators covering structure and organization, content, language, and presentation and display. The data were analyzed using Aiken's *V* coefficient. The results showed that the Aiken's *V* coefficients ranged from 0.79 to 1.00, with an overall mean of 0.89. The mean coefficients were 0.94 for structure and organization, 0.88 for content, 0.83 for language, and 0.90 for presentation and display. Revisions were made based on the validators' comments and suggestions. These results indicate that the developed student worksheets are valid as a learning resource for supporting numeracy learning through the hierarchical organization of mathematical content. Further research is needed to examine the practicality and effectiveness of the worksheets in classroom learning.

**Keywords**— Hierarchical Organization of Mathematical Content; Numeracy Learning; Student Worksheets; Primary School

*Manuscript received September 5, 2026; revised September 25, 2026; accepted October 7, 2026*

### I. Introduction

Numeracy is a fundamental component of mathematics education because it enables students to use mathematical knowledge to reason about quantities, interpret information, solve problems, and make decisions in meaningful contexts. For primary school students, the development of numeracy is particularly important because early mathematical skills provide a foundation for subsequent mathematical learning. Research has indicated that early numerical skills are associated with later mathematical achievement, highlighting the importance of supporting students' mathematical development from the beginning of formal schooling (Devlin et al., 2022; Ruiz et al., 2024). Therefore, primary mathematics learning needs to provide students with opportunities not only to perform mathematical procedures but also to develop connected and meaningful understandings of mathematical concepts.

Mathematical knowledge is not composed of isolated concepts; rather, concepts are interconnected, and some concepts provide important foundations for learning subsequent concepts. Such connections can be described through prerequisite relationships, in which a learner needs to study one concept before approaching another (Kirillovich et al., 2021). Recognizing these relationships is important because students' understanding of prior mathematical knowledge can provide a foundation for engaging with subsequent mathematical content. Thus, attention to the relationships among mathematical concepts is relevant when organizing mathematical

content for instruction, particularly at the primary school level, where students are developing foundational mathematical knowledge.

Student worksheets provide a practical means of translating mathematical content into structured learning activities that students can engage with directly. In primary mathematics education, some previous development studies have designed student worksheets around particular pedagogical approaches, such as Realistic Mathematics Education and contextual teaching and learning (Monika & Ramadan, 2022; Rijal et al., 2024). These studies illustrate how worksheets can be designed not merely as collections of exercises, but as structured learning resources that guide students through mathematical activities. This characteristic makes student worksheets a relevant medium for implementing a deliberate organization of mathematical content and its prerequisite relationships.

Although prerequisite knowledge has been incorporated into some mathematics worksheet designs, its role has generally been addressed in relation to the learning of a particular mathematical topic. For example, Sariyani et al. (2021) developed a student worksheet for straight-line equations by incorporating structured prerequisite material to support students' learning of the target topic. At the curriculum level, other research has emphasized the importance of systematically sequencing mathematical concepts by considering students' assumed prior knowledge and conceptual relationships among topics (Chinofunga et al., 2022). However, these perspectives leave room to further explore how prerequisite–extension relationships can be used as an organizing principle across related mathematical contents and subsequently translated into the structure of primary school student worksheets. This issue is particularly relevant for early mathematics, where foundational concepts are developed across interconnected content strands.

To address this design issue, the present study develops student worksheets based on a hierarchical organization of mathematical content. In this study, hierarchical organization refers to the arrangement of mathematical content according to meaningful prerequisite–extension relationships among concepts. It does not imply that all mathematical topics must follow a single linear sequence from easy to difficult. Rather, where a prerequisite relationship exists, foundational content is positioned to support subsequent content, while relatively independent content strands are organized according to their own internal progression. This approach is intended to make relationships among mathematical concepts more explicit within the learning activities provided in the student worksheets.

The developed product consists of seven student worksheets designed based on the Learning Outcomes (Capaian Pembelajaran) for Phase A of the Indonesian primary mathematics curriculum. Six worksheets address the Numbers element, covering number representation, place value and number composition and decomposition, comparison and ordering of numbers, addition, subtraction, and basic fractions. The seventh worksheet addresses the Algebra element through non-number patterns. These contents were selected from the Phase A learning outcomes and subsequently organized by considering meaningful prerequisite–extension relationships among related mathematical concepts. The worksheets present the content through contextual situations and structured activities, allowing students to engage with mathematical ideas progressively while maintaining distinct content strands where direct prerequisite relationships are not evident.

Therefore, this study aims to develop student worksheets based on the hierarchical organization of mathematical content to support numeracy learning among Phase A primary school students. The worksheets were developed using the 4-D model, consisting of the define, design, develop, and disseminate stages. The present study focuses on the development and content validation of the worksheets, particularly in terms of their structure and organization, content, language, and presentation. By incorporating meaningful prerequisite–extension relationships into the organization of mathematical content, this study seeks to contribute a design perspective for developing primary mathematics learning resources that support students in building connected mathematical understanding.

## II. Literature Review

### A. Numeracy Learning in Primary Mathematics

Numeracy refers to the capacity to use mathematical knowledge and reasoning to understand and respond to situations involving mathematics. It extends beyond the ability to perform calculations, as mathematically literate individuals are expected to formulate, employ, and interpret mathematics in a variety of contexts. This includes using mathematical concepts, procedures, facts, and tools to describe, explain, and solve problems, as well as reasoning about mathematical information and evaluating the reasonableness of outcomes (OECD, 2023). From this perspective, numeracy learning involves developing students' capacity to use mathematics meaningfully rather than focusing exclusively on the mastery of isolated procedures.

In the early years of formal schooling, numeracy encompasses a range of foundational mathematical skills that support children's engagement with subsequent mathematical learning. Speyer et al. (2024) describe early

numeracy as an important area of mathematical development in children up to eight years of age and emphasize the need for valid measures to assess its different components. Similarly, Ruiz et al. (2024), through a systematic review and meta-analysis of 54 longitudinal studies involving 13,453 participants, found significant positive associations between domain-specific numeracy skills assessed at the beginning of formal schooling and later mathematics achievement during the primary school years. However, the strength of these associations varied across studies and measures, indicating that early numeracy is multidimensional and that no single domain-specific skill can be considered a definitive predictor of later mathematical achievement.

Numeracy learning in primary school therefore needs to provide opportunities for students to develop foundational mathematical knowledge while using that knowledge in meaningful situations. Students need to engage with mathematical concepts, representations, relationships, and problem situations in ways that allow them to connect existing knowledge with new mathematical ideas. This consideration is particularly relevant in the early grades, where foundational concepts in number, operations, fractions, and patterns are introduced and developed. Consequently, attention to how mathematical content is organized can contribute to learning experiences that help students build connected mathematical understanding.

### *B. Prerequisite Relationships and the Organization of Mathematical Content*

Mathematical knowledge is interconnected, with some concepts providing foundations for understanding subsequent concepts. These connections can be described through prerequisite relationships, in which one concept is considered a prerequisite for another when learners need to acquire the former before approaching the latter (Kirillovich et al., 2021). Prerequisite relationships therefore represent dependencies among mathematical concepts and provide a basis for examining how mathematical knowledge can be organized in relation to what learners need to know before engaging with subsequent content.

The relevance of prior mathematical knowledge to subsequent learning is also supported by empirical research. Geary et al. (2017), through an eight-year longitudinal study, found that domain-specific mathematical knowledge contributed to subsequent mathematics achievement, with the influence of specific mathematical competencies changing across development. More directly, Alreshidi (2023) found that enhancing students' topic-specific prior mathematical knowledge before introducing new topics improved several aspects of their subsequent mathematics performance. These findings suggest that previously acquired mathematical knowledge is not merely a record of what students have learned but can serve as a foundation for engaging with new mathematical content.

The role of prerequisite knowledge has implications for the sequencing of mathematical content. Content sequencing involves determining how mathematical concepts are ordered so that relevant prior knowledge can support subsequent learning. Chinofunga et al. (2022) proposed a framework for systematically sequencing mathematics concepts by considering students' assumed prior knowledge and identifying conceptual relationships across levels of mathematical knowledge. From this perspective, sequencing is not simply a matter of arranging topics from easy to difficult; rather, it involves considering the conceptual dependencies and knowledge needed to support students' movement toward subsequent mathematical content.

For primary mathematics, this perspective suggests that mathematical content can be organized according to meaningful prerequisite–extension relationships while recognizing that not all content strands are directly dependent on one another. Related concepts may therefore be arranged hierarchically when a meaningful prerequisite relationship exists, whereas relatively independent strands can follow their own internal progression. Such an organization provides a basis for making conceptual dependencies more explicit in learning resources and, in particular, for translating relationships among mathematical concepts into the structure of student learning activities.

### *C. Student Worksheets in Primary Mathematics Learning*

Student worksheets can function as structured learning resources that guide students through learning activities and provide opportunities to engage directly with mathematical concepts. In mathematics learning, a worksheet can organize instructions, representations, questions, and activities into a sequence that supports students' engagement with the content. Thus, a student worksheet is not merely a collection of exercises but can serve as a learning resource through which particular instructional principles are translated into concrete activities for students.

In primary mathematics education, previous development studies have demonstrated that student worksheets can be designed to incorporate specific pedagogical approaches and learning objectives. For example, Andeswari et al. (2021) developed a mathematics student worksheet based on Problem-Based Learning for Grade IV elementary school students, with the development focusing on the feasibility of the worksheet as a learning resource. Similarly, Anawati et al. (2024) developed an ethnomathematics-based mathematics worksheet for Grade IV students and examined its quality through expert validation and student

responses. These studies illustrate that the design of student worksheets can integrate particular learning principles into the organization of mathematical activities rather than treating worksheets solely as supplementary practice materials.

The pedagogical orientation embedded in a worksheet consequently influences how mathematical content is selected, presented, and organized for students. Existing studies have explored worksheet development through approaches such as problem-based learning and ethnomathematics, demonstrating that worksheets can be deliberately structured to support particular learning processes and objectives. However, relatively less attention has been given to the organization of mathematical content itself as a basis for structuring worksheet activities, particularly through meaningful prerequisite–extension relationships among mathematical concepts. This perspective opens an opportunity to consider the organization of mathematical content as an additional design principle for developing student worksheets in primary mathematics learning.

#### *D. Hierarchical Organization as a Design Principle for Student Worksheets*

The organization of mathematical content can be informed by the relationships among concepts that students are expected to learn. When a mathematical concept provides an important foundation for understanding another concept, the two concepts can be organized according to a prerequisite–extension relationship. A prerequisite relationship refers to a condition in which a learner needs to study one concept before approaching another concept (Kirillovich et al., 2021). From this perspective, hierarchical organization refers to arranging mathematical content based on meaningful conceptual dependencies rather than simply ordering topics according to increasing difficulty. Such an organization can occur across related concepts as well as within a particular content strand, depending on the nature of the mathematical relationships involved.

This perspective should be distinguished from the concept of learning progression. Learning progression research primarily concerns how students' mathematical understanding develops over time, including changes in the sophistication of students' thinking, and requires conceptual and empirical support to establish developmental pathways (Fonger et al., 2018; Graf et al., 2021). In contrast, the hierarchical organization used in the present study refers to a design decision concerning the organization of mathematical content in a learning resource. It identifies relevant prerequisite–extension relationships among content and uses these relationships to inform the order and structure of learning activities, without assuming that all content forms a single linear developmental pathway.

The use of hierarchical content in primary mathematics has also been explored in assessment development. Putri et al. (2025) developed a numeracy test based on hierarchical content for Phase A in the Numbers and Algebra element and identified five hierarchical content areas represented in the developed test items. The study was designed to provide information about students' numeracy proficiency while also identifying prerequisite content that had not yet been mastered. This work demonstrates the potential of hierarchical content for making relationships among mathematical content more explicit in the context of numeracy assessment.

Building on this perspective, the present study extends the use of hierarchical content from assessment design to the design of student learning resources. In the developed worksheets, prerequisite–extension relationships are used to inform the organization of mathematical activities. For example, within the Numbers strand, activities related to number representation and place value provide a foundation for subsequent activities involving the comparison and ordering of numbers. In contrast, content strands without an explicit prerequisite relationship are not forced into a single sequence but are organized according to their own internal mathematical progression. Hierarchical organization is therefore used in this study as a design principle for structuring student worksheets so that meaningful relationships among mathematical concepts become visible within students' learning activities.

### **III. Methods**

#### *A. Research Design*

This study employed a research and development (R&D) design to develop a student worksheet based on the hierarchical organization of mathematical content for numeracy learning in Phase A of primary school. The development procedure adopted the 4-D model proposed by Thiagarajan et al. (1974), consisting of four stages: Define, Design, Develop, and Disseminate. The model was selected to provide a systematic procedure for identifying learning needs, designing the learning resource, developing and validating the product, and disseminating the developed student worksheets. The development in this study focused on producing and validating the student worksheets. Therefore, the study did not include formal testing of the practicality or effectiveness of the developed product.

## *B. Development Procedures*

### *1. Define*

The Define stage was conducted to identify the learning needs, learner characteristics, mathematical content, and learning objectives that served as the basis for developing the student worksheets. This stage consisted of initial analysis, learner analysis, task analysis, concept analysis, and formulation of learning objectives.

The initial analysis examined the conditions of numeracy learning and the learning resources used in Phase A. The learner analysis considered the characteristics of primary school students and the need for contextual and visual representations in learning activities. The task analysis focused on the learning outcomes of Phase A mathematics, particularly the Numbers and Algebra elements. The selected contents included whole numbers up to 100, place value, comparison and ordering of numbers, addition and subtraction, basic fractions, and non-number patterns.

The concept analysis focused on identifying meaningful relationships among mathematical concepts. Concepts with prerequisite relationships were organized sequentially so that foundational knowledge could support subsequent concepts. For example, number representation was positioned before place value, while place value provided a foundation for comparing and ordering numbers. At the same time, content strands without a direct prerequisite relationship were organized according to their respective internal conceptual relationships. This analysis resulted in the selection of seven student worksheets covering number representation; place value, decomposition, and composition; comparison and ordering of numbers; addition; subtraction; basic fractions; and non-number patterns.

Finally, the learning objectives were formulated based on the selected mathematical contents and the expected learning outcomes. The objectives included reading and writing numbers up to 100, understanding place value and number composition and decomposition, comparing and ordering numbers, performing addition and subtraction within 20, understanding basic fractions, and recognizing, imitating, and extending non-number patterns.

### *2. Design*

The Design stage translated the results of the Define stage into the structure, content, activities, and visual format of the student worksheets. The mathematical contents were organized according to meaningful prerequisite–extension relationships, rather than being arranged merely from easy to difficult.

Within the Numbers strand, activities involving number representation were positioned as a foundation for place value, decomposition, and composition, which subsequently supported activities involving comparison and ordering of numbers. Addition and subtraction were treated as related but relatively independent content strands. Basic fractions and non-number patterns were organized according to their respective internal conceptual relationships.

Based on this organization, seven student worksheets were designed for Phase A mathematics. Each worksheet consisted of learning objectives, contextual mathematical content, learning activities or exercises, and reflection activities. The worksheets also incorporated contextual illustrations and visual representations to support students' engagement with the mathematical concepts. The initial product was therefore designed not only to present mathematical content but also to translate the identified conceptual relationships into structured student activities.

### *3. Develop*

The Develop stage focused on producing the initial student worksheets and evaluating their validity through expert and practitioner validation. The initial product consisted of seven student worksheets, each containing a cover, learning objectives, contextual illustrated content, learning activities, exercises, and reflection. The introductory material was presented using visual narratives, while the exercises were presented in a worksheet format to maintain readability.

The product was evaluated by six validators, consisting of four university lecturers as expert validators and two elementary school teachers as practitioner validators. The validation focused on four aspects: structure and organization, content, language, and presentation and display. The validation instrument comprised 25 indicators distributed across these four aspects.

The validators assessed each indicator using a five-point rating scale, ranging from 1 (lowest rating) to 5 (highest rating). The use of the five-point scale is reflected in the validation data, in which the ratings assigned by the six validators predominantly fell within the upper part of the scale (mostly 4 and 5), with a small number of ratings of 3 recorded on individual language indicators, consistent with the minimum Aiken's *V* of 0.79 obtained in that aspect. Following the validation process, revisions were made based on the validators'

comments and suggestions. The revisions included improvements to wording and instructions, contextual illustrations, question formats, and the consistency of the visual layout.

#### 4. Disseminate

The Disseminate stage was conducted through a community service activity in which the developed student worksheets were introduced and presented to participants. The dissemination focused on introducing the rationale underlying the hierarchical organization of mathematical content, the structure of the student worksheets, and examples of the learning activities contained in the product.

The dissemination activity functioned as an initial means of introducing the developed product and obtaining responses concerning its potential use in primary numeracy learning. It was not conducted as a formal practicality or effectiveness test. Formal testing of the practicality and effectiveness of the student worksheets was therefore left for subsequent research.

#### C. Validation Participants and Instrument

The validation panel consisted of six validators purposively selected to obtain balanced theoretical and practical expertise relevant to primary mathematics education. Four validators were university lecturers with formal academic qualifications in mathematics or mathematics education (holding either a Master's or Doctoral degree) and at least five years of teaching experience in teacher education programs. The remaining two validators were elementary school teachers with a minimum of five years of teaching experience in Phase A of the Indonesian primary curriculum and demonstrated involvement in curriculum development or teacher-training activities at the school level. This composition was intended to ensure that the validation process reflected both academic rigor and classroom authenticity. The panel size of six validators is consistent with content-validity practices in educational instrument development, which commonly recommend a minimum of five to ten expert reviewers to obtain stable content-validity estimates (Aiken, 1985; Speyer et al., 2024).

The validation instrument was developed to evaluate the quality of the student worksheets across four aspects: structure and organization, content, language, and presentation and display. The instrument was constructed through a systematic three-step procedure. First, indicators were derived from established guidelines on the development of educational learning materials and adapted to the specific characteristics of hierarchically organized numeracy resources. Second, the initial pool of indicators was reviewed by two experts in educational assessment who were not part of the validation panel; their feedback led to minor adjustments in wording, the elimination of redundant items, and the sharpening of indicator definitions to improve clarity and mutual exclusiveness. Third, the revised instrument was pilot-tested with one expert lecturer prior to full deployment to confirm that all indicators were comprehensible and applicable to the developed worksheets, following which the final version consisting of 25 indicators was established.

The 25 indicators were distributed across the four aspects as follows. The Structure and Organization aspect (6 indicators) assessed the clarity of learning objectives, the alignment between activities and learning outcomes, the systematic arrangement of learning activities, the clarity of instructions, the internal coherence of each worksheet, and the appropriateness of the hierarchical organization of the mathematical content. The Content aspect (7 indicators) assessed the accuracy of mathematical concepts, the alignment with Phase A learning outcomes, the proportionality of main and supporting concepts, the developmental appropriateness for Phase A students, the use of relevant contextual examples, the support provided for hierarchical relationships among concepts, and the organization of knowledge from foundational to more advanced content. The Language aspect (6 indicators) assessed the clarity and simplicity of the language used, the appropriateness of vocabulary for Phase A students, the readability of instructions and questions, the consistency of terminology, the use of communicative language, and spelling, punctuation, and grammatical accuracy. The Presentation and Display aspect (6 indicators) assessed the layout organization, the readability of the font, the clarity of images and diagrams, the consistency of colors and visual design, the overall attractiveness of the worksheets, and the application of visual hierarchy to support engagement with the mathematical content.

The validation procedure was conducted in a structured manner over a two-week period. Each validator received (a) the seven developed student worksheets in printed form, (b) the validation instrument containing the 25 indicators, (c) a standardized rating scale ranging from 1 (very poor) to 5 (excellent), and (d) written instructions clarifying the meaning of each rating level and requesting independent judgment. Validators were asked to review the worksheets individually and to record both quantitative ratings for each indicator and qualitative comments regarding strengths, weaknesses, and suggestions for improvement. All validators provided informed consent before participating, and their identities were kept confidential during the analysis. The completed instruments were returned electronically or in person, after which the quantitative ratings were compiled for Aiken's V computation and the qualitative comments were systematically organized to inform the subsequent revision stage of the developed worksheets.

#### D. Data Analysis

The validity of the student worksheets was analyzed using Aiken's  $V$  coefficient (Aiken, 1985). This coefficient was selected because it is specifically designed to quantify the degree of content-related agreement among a panel of validators regarding each individual indicator, providing a stable content-validity estimate even with a small number of validators. Aiken's  $V$  was calculated using the formula  $V = \sum s / [n(c - 1)]$ , where  $s = r - l_0$ ,  $r$  denotes the rating assigned by each validator,  $l_0$  denotes the lowest possible rating,  $c$  denotes the highest possible rating, and  $n$  denotes the number of validators. In this study, the validation instrument used a five-point rating scale ranging from 1 to 5 and involved six validators; therefore,  $l_0 = 1$ ,  $c = 5$ , and  $n = 6$ , yielding a denominator of 24 for each indicator. The resulting Aiken's  $V$  coefficients were interpreted using the following validity criteria:  $V \leq 0.40$  was categorized as less valid,  $0.40 < V < 0.80$  as valid, and  $V \geq 0.80$  as very valid. In addition to the quantitative validity analysis, the comments and suggestions provided by the validators were analyzed descriptively and used as the basis for revising the student worksheets. The final product was therefore established through the combination of quantitative validity evidence and qualitative feedback from the validators.

### IV. Results and Discussion

#### A. Research Results

##### 1. Development of the Student Worksheets

The development process produced seven student worksheets based on the hierarchical organization of mathematical content for numeracy learning in Phase A of primary school. The worksheets were developed using the four stages of the 4-D model: Define, Design, Develop, and Disseminate. At the Define stage, the development process began with an analysis of learning needs, learner characteristics, learning tasks, mathematical concepts, and learning objectives. The analysis focused on the Numbers and Algebra elements of Phase A. The selected mathematical contents included number representation, place value and number composition and decomposition, comparison and ordering of numbers, addition, subtraction, basic fractions, and non-number patterns.

The concept analysis was used to identify meaningful relationships among mathematical contents. Within related contents, prerequisite–extension relationships were considered in determining the organization of the learning activities. For example, activities involving number representation were positioned before activities involving place value, decomposition, and composition, while place value provided a foundation for activities involving comparison and ordering of numbers. Contents without a direct prerequisite relationship were organized according to their respective internal conceptual relationships.

At the Design stage, the results of the analysis were translated into the structure and visual design of seven student worksheets. Each worksheet was developed around a contextual theme and included learning objectives, contextual mathematical content, learning activities or exercises, and reflection activities. The worksheets also incorporated visual illustrations and contextual situations intended to support students' engagement with the mathematical content. The seven worksheets covered the following contents.

Table 1. The Developed Student Worksheets

| Worksheet | Mathematical Content                        | Contextual Theme           |
|-----------|---------------------------------------------|----------------------------|
| 1         | Reading and writing numbers up to 100       | My School                  |
| 2         | Place value, decomposition, and composition | Traditional Market         |
| 3         | Comparing and ordering numbers              | Playground                 |
| 4         | Addition up to 20                           | Fruit Garden               |
| 5         | Subtraction up to 20                        | My Garden                  |
| 6         | Basic fractions                             | Sharing Food               |
| 7         | Non-number patterns                         | Children's Games at School |

At the Develop stage, the seven initial worksheets were produced. Each worksheet contained a cover, learning objectives, contextual illustrated material, learning activities or exercises, and reflection activities. The introductory sections used visual narratives resembling comic panels, while the exercises were presented in a relatively simple worksheet format to maintain readability. Figure 1 presents an overview of the seven student worksheets developed for Phase A mathematics learning.



Figure 1. Overview of the Developed Student Worksheets

The worksheets were organized around different mathematical contents and contextual themes while maintaining a consistent overall visual structure. The organization of the worksheets reflected different types of mathematical relationships. Worksheets 1–3 addressed related number concepts, progressing from number representation to place value, composition and decomposition, and subsequently to comparison and ordering. Worksheets 4 and 5 addressed addition and subtraction as related but relatively independent operations. Worksheet 6 addressed basic fractions through activities involving whole quantities, equal partitioning, and fractional representation, while Worksheet 7 addressed non-number patterns through activities involving recognition, imitation, continuation, and creation of patterns.

At the Disseminate stage, the developed worksheets were introduced through a community service activity. The activity presented the rationale for the hierarchical organization of mathematical content, the structure of the worksheets, and examples of learning activities contained in the product. The dissemination served as an introduction to the developed product and an opportunity to obtain initial responses regarding its potential use in primary numeracy learning. It was not conducted as a formal practicality or effectiveness test.

## 2. Validation Result

The developed student worksheets were evaluated by six validators, consisting of four university lecturers as expert validators and two elementary school teachers as practitioner validators. The validation instrument comprised 25 indicators distributed across four aspects: structure and organization, content, language, and presentation and display. The validators assessed the indicators using a five-point rating scale ranging from 1 to 5. The validation process covered the quality and suitability of the developed worksheets in terms of their organization, mathematical content, language, and visual presentation. The Aiken's V coefficients obtained across the 25 indicators ranged from 0.79 to 1.00, with an overall mean of 0.89. The results for each validation aspect are presented in Table 2.

Table 2. Summary of Student Worksheet Validation Results

| Validation Aspect          | Number of Indicators | Aiken's V Range | Mean |
|----------------------------|----------------------|-----------------|------|
| Structure and Organization | 6                    | 0.86–1.00       | 0.94 |
| Content                    | 7                    | 0.83–0.92       | 0.88 |
| Language                   | 6                    | 0.79–0.88       | 0.83 |
| Presentation and Display   | 6                    | 0.88–0.92       | 0.90 |
| Overall                    | 25                   | 0.79–1.00       | 0.89 |

The Structure and Organization aspect obtained the highest mean Aiken's V coefficient, at 0.94. The individual indicators ranged from 0.86 to 1.00. The highest coefficients were obtained for the clarity of learning objectives and the clarity and conciseness of instructions, both with a coefficient of 1.00. The Content aspect obtained a mean coefficient of 0.88, with individual coefficients ranging from 0.83 to 0.92. The assessed indicators included alignment with learning outcomes, proportionality of main and supporting concepts, developmental appropriateness, contextual examples, support for hierarchical relationships among concepts, conceptual accuracy, and the organization of knowledge from foundational to more advanced content. The Language aspect obtained a mean coefficient of 0.83, the lowest among the four aspects. Its individual coefficients ranged from 0.79 to 0.88. The coefficient of 0.79 was obtained for the indicator concerning spelling, punctuation, and grammatical accuracy. Based on the validity criteria adopted in the study, this indicator falls within the valid category, whereas coefficients of 0.80 or higher fall within the very valid category. The Presentation and Display aspect obtained a mean coefficient of 0.90, with individual coefficients ranging from 0.88 to 0.92. The indicators covered layout organization, font readability, clarity of images and diagrams, consistency of colors and design, attractiveness, and the application of visual hierarchy. Overall, the developed student worksheets obtained an Aiken's V mean of 0.89, indicating a high level of validity across the evaluated aspects. The validation results were subsequently used as the basis for revising the worksheets.

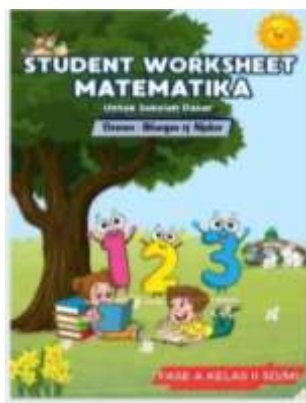
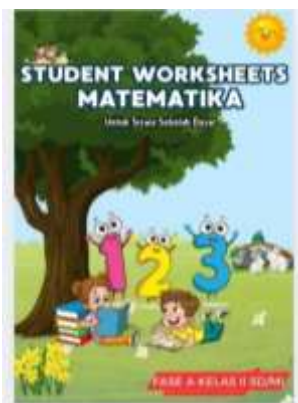
### 3. Revisions Based on Validator Feedback

Following the validation process, several components of the student worksheets were revised based on the comments and suggestions provided by the validators. The revisions addressed both content presentation and visual design, including the font, illustrations, color contrast, contextualization, question wording, question format, and consistency of the worksheet layout. The revision document specifically records changes made after expert validation, including adjustment of the font size from 13 to 14, improvement of image clarity and color contrast, and addition of a concept map.

Table 3. Revisions to the Student Worksheets Based on Validator Feedback

| No. | Component Revised                 | Revision Made                                                                                                                |
|-----|-----------------------------------|------------------------------------------------------------------------------------------------------------------------------|
| 1   | Cover                             | The relevant curriculum element was added to the cover to clarify the content represented in the worksheet.                  |
| 2   | Visual design                     | Font size and type, background color, and color contrast were adjusted to improve readability and visual consistency.        |
| 3   | Question wording and instructions | Inconsistent forms of instructions were revised and standardized across the worksheets.                                      |
| 4   | Contextualization                 | Several learning contexts and question narratives were revised to make them more relevant to students' everyday experiences. |
| 5   | Question format and illustrations | Several question formats were revised, image sizes were adjusted, and inappropriate answer options were corrected.           |
| 6   | Visual consistency                | Background designs used for subheadings were standardized across the seven worksheets.                                       |

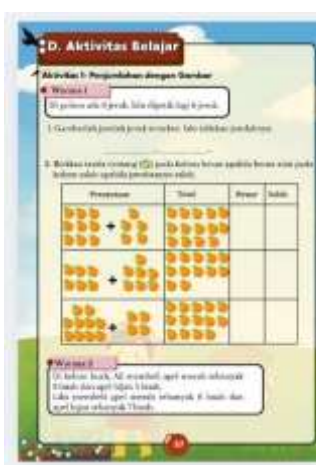
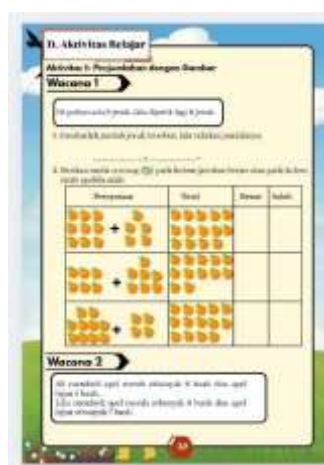
The revision records provide examples of these changes. For example, the cover was revised to include the relevant curriculum element, the color scheme of one worksheet was adjusted, and a context concerning the sale of office supplies was replaced with a traditional-market context. Other revisions involved question wording, contextual narratives, image sizes, answer options, and the consistency of background designs across the worksheets.



(a) Cover revision



(b) Context and question revision



(c) Layout and visual revision

Figure 2. Examples of Revisions to the Student Worksheets Based on Validator Feedback

## B. Discussion

### 1. Hierarchical Organization of Mathematical Content

The findings demonstrate that hierarchical organization can be operationalized as a design principle for structuring mathematical learning activities rather than as a requirement to arrange all mathematical topics in a single linear sequence. In the developed worksheets, the strongest cross-worksheet relationship was found within the number strand, in which number representation preceded place value, composition and decomposition, and comparison and ordering. This arrangement reflects the broader principle of curricular coherence, in which mathematical learning is organized so that students can progress from foundational knowledge toward increasingly connected and abstract understandings (OECD, 2024).

The importance of such organization is also supported by recent research on prior mathematical knowledge. Cook et al. (2024), for example, showed that the effects of instruction in mathematical equivalence varied according to students' prior knowledge and the strategies they had developed before instruction. Similarly, Boomgaarden et al. (2024) reported that students' existing knowledge can influence how they benefit from subsequent instructional support. These findings support the rationale for making relationships between foundational and subsequent mathematical content explicit in learning resources, although they do not imply that every mathematical topic must follow one predetermined sequence.

The present product also demonstrates why hierarchical organization should not be interpreted simply as arranging content from easy to difficult. Worksheets addressing addition and subtraction were treated as related but relatively independent strands, while fractions and non-number patterns were organized according to their own internal relationships. This design recognizes that mathematical curricula contain multiple conceptual pathways rather than one universal hierarchy. The 2024 OECD report similarly emphasizes the importance of coherent sequences while recognizing progression from concrete to abstract understanding and connections among mathematical ideas.

The use of visual and structural representations also supports this organization. Recent work by Chinofunga et al. (2025) indicates that visual resources can help learners organize and connect mathematical procedures and make sequences of ideas more explicit. Although their study focused on procedural flowcharts and older

students, the underlying implication is relevant to the present design: visual organization can make relationships among mathematical ideas and activities more visible to learners.

Importantly, the hierarchical organization developed in this study should not be interpreted as an empirically established learning progression. The present study determines relationships among mathematical content for the purpose of designing a learning resource; it does not establish developmental levels of students' mathematical thinking. Thus, the seven worksheets represent a content organization framework, rather than seven empirically validated stages of cognitive development.

This distinction strengthens the contribution of the present study. Rather than treating hierarchical content as a characteristic of students' development, the study demonstrates how relationships among mathematical concepts can be translated into the architecture of a student worksheet. The result is a learning resource in which prerequisite relationships are reflected in the arrangement of activities while relatively independent mathematical strands retain their own internal organization.

## 2. *Validity of the Developed Student Worksheets*

The high validity obtained across the four evaluated aspects indicates that the developed worksheets met the predefined criteria for structure and organization, content, language, and presentation. This finding is consistent with recent mathematics worksheet development research showing that contextual and visually supported worksheets can achieve favorable expert evaluations when their content, language, and design are systematically developed.

For example, Aisyah & Juandi (2025) developed contextual student worksheets for numeracy learning on number topics and reported high expert evaluations in content, language, and design. Similarly, Yuliandari et al. (2025) developed mathematics worksheets integrating contextual and cultural elements for elementary school students, with expert validation covering material, media, language, and teaching-practice dimensions. These studies indicate that the quality of a mathematics worksheet depends on the alignment of several dimensions rather than mathematical content alone.

In the present study, structure and organization received the highest mean validity coefficient. This result is particularly meaningful because organization was not merely a formatting feature but a central component of the hierarchical-content design. The high ratings suggest that the relationships among learning objectives, activities, numbering, and worksheet components were sufficiently clear to the validators. The finding therefore provides supporting evidence that the intended content organization was successfully translated into the structure of the learning resource.

The content aspect also obtained a high validity coefficient. This result indicates that the selected mathematical content, its alignment with the intended learning outcomes, its developmental appropriateness, and its contextual presentation were positively evaluated by the validators. Recent worksheet research has likewise emphasized contextual relevance as an important component in developing mathematics learning resources for elementary students. Aisyah & Juandi (2025), for instance, explicitly positioned contextualization as a response to the problem of learning materials that are insufficiently connected to students' real-life environments.

The language aspect produced the lowest mean among the four dimensions, although it remained within the high-validity range overall. This finding is useful because it identifies an area requiring greater attention in the development process. The validator feedback led to revisions in question wording and instructions, including the alignment of command forms across activities. Thus, the quantitative result was complemented by qualitative evidence that identified specific linguistic features requiring refinement. Specifically, the indicator concerning spelling, punctuation, and grammatical accuracy obtained a coefficient of  $V = 0.79$ , which falls in the "valid" rather than the "very valid" category according to the classification adopted in this study. This indicator was accordingly addressed in the revision stage through targeted improvements to wording, instructions, and question format.

The high rating for presentation and display is also relevant to the characteristics of the product. The worksheets incorporated contextual illustrations, visual narratives, color, and structured page layouts. Recent studies of elementary mathematics worksheets similarly employ contextual and visual elements to make learning resources more engaging and meaningful (Aisyah & Juandi, 2025; Yuliandari et al., 2025). However, the present study adds a different organizing principle by combining these visual and contextual features with a hierarchical organization of mathematical content.

## 3. *Validator Feedback and Product Refinement*

An important finding of the development process is that validation functioned as more than a procedure for assigning a numerical validity coefficient. The validators' feedback resulted in concrete modifications to the student worksheets, including changes to wording, contextual situations, illustrations, color contrast, question

formats, and visual consistency. This demonstrates the formative role of validation in an R&D process: expert and practitioner judgments can identify specific aspects of a learning resource that require refinement before wider use.

The revisions to question wording are particularly consistent with the relatively lower result obtained for the language aspect. Several instructions were standardized, while some question formats and answer options were revised. The contextual situations were also refined; for example, one activity was changed from an office-supply sales context to a traditional-market context. These revisions show that contextualization was not treated merely as the addition of illustrations or everyday settings, but also involved ensuring that the narrative and mathematical tasks were appropriately aligned.

The visual revisions likewise demonstrate that the development process was iterative. Font size and type, image clarity, color contrast, and the consistency of subheading backgrounds were adjusted following validation. This is relevant because recent worksheet development studies have similarly treated content, language, and visual design as interconnected dimensions of learning-resource quality rather than as independent components (Mukhlisa et al., 2026; Yuliandari et al., 2025).

The present findings therefore suggest that the value of validation in instructional-material development lies not only in determining whether a product meets a numerical threshold, but also in identifying what should be improved and why. The combination of quantitative judgments and qualitative feedback enabled the developed worksheets to undergo targeted refinement before dissemination.

#### *4. Implications and Limitations*

The findings have several implications for the development of primary mathematics learning resources. First, hierarchical organization can be considered as a content-design principle that complements, rather than replaces, pedagogical approaches such as contextual learning. Recent worksheet research has demonstrated the value of contextualization for numeracy learning, including the development of worksheets linked to local environments and students' real-life experiences (Aisyah & Juandi, 2025; Mukhlisa et al., 2026). The present study adds that the internal organization of the mathematical content itself can also be deliberately designed around relationships among concepts.

Second, the findings suggest that the organization of mathematical content and the contextual presentation of activities can coexist within the same learning resource. The contextual themes used in the worksheets provide situations through which mathematical ideas are presented, while the hierarchical organization determines how related mathematical ideas are connected across and within worksheets. This combination may provide a useful design framework for developers of early mathematics learning resources.

Nevertheless, the findings must be interpreted within the scope of the study. The research established product validity, but it did not formally examine practicality or effectiveness through classroom implementation. Consequently, the validity coefficient should not be interpreted as evidence that the worksheets improve students' numeracy achievement. Recent worksheet-development studies that claim practicality or effectiveness have included additional implementation or response data beyond expert validation (Mukhlisa et al., 2026).

The dissemination activity in the present study was also intended to introduce the product rather than to provide evidence of classroom effectiveness. Therefore, future research should examine how students and teachers use the worksheets in authentic classroom settings, including their practicality, usability, and potential effects on students' mathematical understanding and numeracy performance.

### **V. Conclusion**

This study developed seven student worksheets based on the hierarchical organization of mathematical content for Phase A primary school students. The worksheets were developed using the 4-D model and organized according to meaningful prerequisite–extension relationships among mathematical concepts. The validation results showed that the worksheets were valid, with Aiken's *V* coefficients ranging from 0.79 to 1.00 and an overall mean of 0.89. The worksheets were considered appropriate in terms of structure and organization, content, language, and presentation. Revisions were also made based on the validators' comments and suggestions. Thus, the developed worksheets provide a valid learning resource for supporting numeracy learning through a more organized connection among mathematical concepts. However, this study did not examine the practicality or effectiveness of the worksheets. Further research is needed to test their use in classroom learning and examine their contribution to students' numeracy development.

### **Conflict of Interest**

The authors declare no conflict of interest related to this study.

## Author Contributions

H.R.P. conceived and designed the study, developed the student worksheets, and drafted the manuscript. L.H.A. contributed to the conceptualization of hierarchical content organization and manuscript review. B.Y.W. contributed to the design and refinement of learning activities. I.N. contributed to the validation instrument and data analysis. V.R.H. contributed to worksheet development and coordination of the validation process. N.I. contributed to manuscript review and editing. All authors have read and approved the final version of this manuscript.

## Funding

This research was supported by the DIPA BLU Fund of Universitas Mataram under contract number 2967/UN18.L1/PP/2025.

## Acknowledgment

This research was supported by the DIPA BLU Fund of University of Mataram under contract number 2967/UN18.L1/PP/2025. The authors would like to express their sincere gratitude to University of Mataram for providing the financial support and resources necessary for the completion of this research.

## References

- Aiken, L. R. (1985). Three coefficients for analyzing the reliability and validity of ratings. *Educational and Psychological Measurement*, 45(1), 131–142. <https://doi.org/10.1177/0013164485451012>
- Aisyah, A., & Juandi, D. (2025). Development of contextual student worksheets based on the Jambi environment to enhance numeracy. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, 14(4), 1745–1759. <https://doi.org/10.24127/ajpm.v14i4.11820>
- Alreshidi, N. A. K. (2023). Enhancing topic-specific prior knowledge of students impacts their outcomes in mathematics. *Frontiers in Education*, 8. <https://doi.org/10.3389/educ.2023.1050468>
- Anawati, S., Seruni, & Mia Intan Lestari. (2024). The development of ethnomathematics-based student worksheets (LKPD) in mathematics for fourth grade students. *EduMatSains : Jurnal Pendidikan, Matematika Dan Sains*, 8(2), 293–301. <https://doi.org/10.33541/edumatsains.v8i2.5336>
- Andeswari, S., Sholeh, D. A., & Zakiyah, L. (2021). Pengembangan lembar kerja peserta didik (LKPD) berbasis problem based learning dalam pembelajaran matematika kelas IV sekolah dasar. *Prima Magistra: Jurnal Ilmiah Kependidikan*, 3(1), 48–61. <https://doi.org/10.37478/jpm.v3i1.1313>
- Boomgaarden, A., Loibl, K., & Leuders, T. (2024). Fostering Learning from Errors—Computer-Based Adaptivity at the Transition Between Problem Solving and Explicit Instruction. *Journal Für Mathematik-Didaktik*, 45(2), 9. <https://doi.org/10.1007/s13138-024-00232-w>
- Chinofunga, M. D., Chigeza, P., & Taylor, S. (2022). A Framework for Content Sequencing from Junior to Senior Mathematics Curriculum. *Eurasia Journal of Mathematics, Science and Technology Education*, 18(4), em2100. <https://doi.org/10.29333/ejmste/11930>
- Chinofunga, M. D., Chigeza, P., & Taylor, S. (2025). How can procedural flowcharts support the development of mathematics problem-solving skills? *Mathematics Education Research Journal*, 37(1), 85–123. <https://doi.org/10.1007/s13394-024-00483-3>
- Cook, S. W., Wernette, E. M. D., Valentine, M., Aldugom, M., Pruner, T., & Fenn, K. M. (2024). How Prior Knowledge, Gesture Instruction, and Interference After Instruction Interact to Influence Learning of Mathematical Equivalence. *Cognitive Science*, 48(2). <https://doi.org/10.1111/cogs.13412>
- Devlin, D., Moeller, K., & Sella, F. (2022). The structure of early numeracy: Evidence from multi-factorial models. *Trends in Neuroscience and Education*, 26, 100171. <https://doi.org/10.1016/j.tine.2022.100171>
- Fonger, N. L., Stephens, A., Blanton, M., Isler, I., Knuth, E., & Gardiner, A. M. (2018). Developing a Learning Progression for Curriculum, Instruction, and Student Learning: An Example from Mathematics Education. *Cognition and Instruction*, 36(1), 30–55. <https://doi.org/10.1080/07370008.2017.1392965>
- Geary, D. C., Nicholas, A., Li, Y., & Sun, J. (2017). Developmental change in the influence of domain-general abilities and domain-specific knowledge on mathematics achievement: An eight-year longitudinal study. *Journal of Educational Psychology*, 109(5), 680–693. <https://doi.org/10.1037/edu0000159>
- Graf, E. A., van Rijn, P. W., & Eames, C. L. (2021). A cycle for validating a learning progression illustrated with an example from the concept of function. *The Journal of Mathematical Behavior*, 62, 100836. <https://doi.org/10.1016/j.jmathb.2020.100836>
- Putri, H. R., Affandi, L. H., Wahyuningsih, B. Y., Nurmawanti, I., Hidayati, V. R., & Wulandari, R. (2025). Pengembangan soal tes numerasi berbasis hierarchical content untuk fase A elemen bilangan dan aljabar. *Griya Journal of Mathematics Education and Application*, 5(4), 1566–1578. <https://doi.org/10.29303/griya.v5i4.926>

- Kirillovich, A., Falileeva, M., Nevzorova, O., Lipachev, E., Dyupina, A., & Shakirova, L. (2021). *Prerequisite Relationships of the OntoMathEdu Educational Mathematical Ontology* (pp. 517–524). [https://doi.org/10.1007/978-3-030-86702-7\\_44](https://doi.org/10.1007/978-3-030-86702-7_44)
- Monika, D., & Ramadan, Z. H. (2022). Student Worksheet Based on Realistic Mathematics Education Approach on Multiplication and Division Material for Grade V Elementary School. *Jurnal Ilmiah Sekolah Dasar*, 6(1), 11–20. <https://doi.org/10.23887/jisd.v6i1.41627>
- Mukhlisa, N., Sapri, N. H., & Krismanto, W. (2026). Instructional Worksheet Development Based on Contextual Learning as Assessment for Learning to Support Numeracy Skills in Elementary Schools. *International Journal of Educational Practice and Policy*, 4(2), 1–24. <https://doi.org/10.66314/ijepp.v4i2.434>
- OECD. (2023). *PISA 2022 Assessment and Analytical Framework*. OECD Publishing. <https://doi.org/10.1787/dfe0bf9c-en>
- OECD. (2024). *An Evolution of Mathematics Curriculum*. OECD Publishing. <https://doi.org/10.1787/0ffd89d0-en>
- Rijal, A., Susilo, A., & Mardicko, A. (2024). Development of mathematics student worksheets based on contextual teaching and learning for elementary school student. *Indonesian Journal of Primary Education*, 8(1), 75–84. <https://doi.org/10.17509/ijpe.v8i1.69622>
- Ruiz, C., Kohnen, S., von Hagen, A., Kwok, F. Y., & Bull, R. (2024). Which domain-specific skills at the beginning of formal schooling predict later mathematical achievement? A systematic review and meta-analysis. *Educational Research Review*, 42, 100583. <https://doi.org/10.1016/j.edurev.2023.100583>
- Sariyani, S., Marzal, J., & Syaiful, S. (2021). Pengembangan LKPD Berbasis Materi Prasyarat Terstruktur pada Materi Persamaan Garis Lurus untuk Kelas VIII SMP/MTs. *Edu-Sains: Jurnal Pendidikan Matematika Dan Ilmu Pengetahuan Alam*, 9(1), 22–31. <https://doi.org/10.22437/jmpmipa.v9i1.12931>
- Speyer, R., Hakkarainen, A., Yoon, S., Kim, J.-H., Windsor, C., Wilkes Gillan, S., Littlefair, D., & Cordier, R. (2024). Content validity of measures in early numeracy in children up to eight years: A COSMIN systematic review. *PLOS ONE*, 19(9), e0308874. <https://doi.org/10.1371/journal.pone.0308874>
- Yuliandari, R. N., Faizah, M., Mubarak, H., Anggraini, D. M., & Salsabila, S. (2025). Development of Student Worksheets Based on Contextual Teaching and Learning Integrated Malang Culture for Elementary School Students. *AL-ISHLAH: Jurnal Pendidikan*, 17(3). <https://doi.org/10.35445/alishlah.v17i3.4712>



Copyright © 2026 by the authors. This is an open access article distributed under the Creative Commons Attribution License (CC BY 4.0), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.