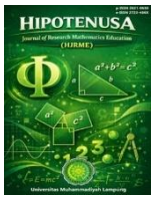
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Design of mathematics teaching material needs to stimulate literacy and numeracy skills at the elementary school level with scaffolding techniques

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A R T I C L E I N F O

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Numeracy Literacy;
Scaffolding;
Elementary School.

A B S T R A C T

The low literacy and numeracy skills of primary school students in Indonesia is an urgent problem that requires a planned and data-driven instructional response. This study aims to analyze the need for mathematics teaching materials that are able to stimulate the literacy and numeracy skills of grade V students through the application of *scaffolding* techniques. The method used is quantitative descriptive with *the Define stage procedure* in the Thiagarajan 4D model. The research subjects consisted of 30 students and 2 mathematics teachers who were selected through *purposive sampling* at SD Muhammadiyah 2 Babat. Data was collected through AKM-based literacy-numeracy ability tests, student needs questionnaires, and structured interviews with teachers. This research is specifically focused on the Define stage in the 4D model as a basis for needs analysis before product design is carried out. The results showed that 68% of learning is still teacher-centered; 55% of questions are procedural; literacy achievement is in the medium category, namely 52% for finding text information and 45% for graphic interpretation; while the numeracy ability of reasoning only reaches 55%. As many as 88% of students stated that they needed step-by-step guidance in teaching materials. Based on the synthesis of the data, a three-level *scaffolding-based* teaching material design specification was formulated that integrates contextual-themed content, adaptive visual elements with a 40: 60 ratio, and *an interactive QR Code feature* as a support for independent learning for elementary school students. The novelty of this research lies in the design specification as the main output that has not been produced by the previous research on the need analysis of literacy-numeracy teaching materials, as well as a direct reference for the development of mathematics teaching materials in elementary schools at the next Design and Development stage.

1. Introduction

The quality of students' literacy and numeracy skills at the elementary school level is still one of the main concerns in the Indonesian and global education landscape. Data released by *Programme for International Student Assessment* (PISA) 2022 ranked Indonesia 77th out of 80 participating countries in the mathematics domain, with an average score of just 366 points far below the OECD average of 472 points [1]. More worryingly, 81.7% of Indonesian students are below the minimum proficiency threshold (*Level 2*) in mathematics, which indicates that the majority of students are not yet able to apply mathematical knowledge in the real-life context of everyday life. This condition is not just a matter of numbers; It reflects a fairly deep

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gap between the demands of 21st century competencies and the realities of learning that takes place in the classroom. This is where the urgency of research on the design of teaching materials that are strategically able to stimulate literacy and numeracy skills becomes very relevant to be studied in depth.

This condition is also reflected in domestic data. The Indonesian Education Report Card released by the Ministry of Primary and Secondary Education noted that the proportion of students who achieved the minimum numeracy competency nationally was only 45.24% in 2022, rising to 62.45% in 2023, and 67.94% in 2024; Meanwhile, the proportion of students who achieve the minimum literacy competency increased from 59.49% (2022) to 68.05% (2023) and 70.03% (2024) [2]. This means that even though the national trend is improving, until 2024 there are still around one-third of Indonesian students who have not reached the minimum numeracy competence, so the need for teaching materials specifically designed to stimulate literacy and numeracy remains urgent at the level of educational units.

Mathematical literacy ability is basically an individual's capacity to formulate, apply, and interpret mathematics in various contexts [1]. It does not stand alone, but is closely intertwined with the ability to read and understand texts, the ability to reason logically, and the ability to communicate thoughts in a structured way. Research conducted by Rezat, Malik, and Leifeld confirms that learning mathematics at any level, including at the elementary level, still requires students' active involvement with mathematical texts, where linguistic understanding, symbolic interpretation, and logical reasoning work in an integrated manner as a single cognitive whole. These findings underscore the importance of presenting teaching materials that not only contain formulas and procedures, but also contain contextual narratives that train students to read, interpret, and use mathematical information holistically [3]. Unfortunately, field observations conducted in this study show that 55% of the math problems given to students are still procedural and direct to algorithms without giving room for students to reason in the context of a story or real situation. The above problems are also inseparable from the tendency of the learning approach that is still centered on teachers (*teacher-centered*). The results of preliminary observations in this study show that 68% of the mathematics learning process takes place in unidirection, without providing adequate opportunities for students to explore concepts independently. This kind of condition creates a significant gap in the development of students' high-level thinking skills. Data *Pre-analysis* The results showed that literacy achievement in interpreting new charts and tables reached 45%, while the ability to reason and simplify complex problems only reached 55%, both of which were in the medium category. This phenomenon is in line with what Carol has expressed that has been widely cited in recent research: that without structured and adaptive instructional support, students tend to be stuck in comfort zones that don't encourage cognitive growth [4].

This initial data was obtained through structured classroom observations conducted by the researcher on all 30 grade V students and 2 mathematics teachers at SD Muhammadiyah 2 Babat during three regular mathematics learning meetings in September 2024, using observation sheets that recorded the pattern of teacher-student interaction and the type of questions given, so that the percentages of 68% and 55% reported were the average of the three observation sessions. Therefore, the availability of teaching materials that are designed responsively to the learning needs of students is a prerequisite that cannot be ignored.

In a theoretical context, efforts to design teaching materials that are able to bridge the gap in students' abilities are very closely related to the concept *scaffolding* which is rooted in Vygotsky's sociocultural theory. *Scaffolding* defined as temporary instructional support provided to learners in *Zone of Proximal Development* (ZPD) is the range between what students are able to do independently and what they are able to achieve with guidance. In the practice of mathematics learning, the application of techniques *scaffolding* which is effective has been proven to be able to increase student engagement and understanding in a measurable way. Chen, Chen, Zuo, and Hou show that integration *Multi-representational scaffolding* in mathematics learning activities significantly increases learning motivation and cognitive flow (*Flow*students, although design adjustments are still needed so that the impact on learning outcomes is optimal [5]. Meanwhile, Rezat et al.'s research emphasizes that the *Scaffold* Planned starting from the guide *close reading* until the gradual instruction is able to foster students' learning independence progressively [3]. Selection *scaffolding* as a design framework in this study, compared to other approaches such as Realistic Mathematics Education or game based learning, based on its characteristics that directly bridge students' ZPD through multi-level assistance that can be systematically reduced as independence increases. Thus, scaffolding acts as a conceptual link between mathematical literacy skills, namely reading and interpreting texts, and numeracy skills, namely reasoning and operating mathematical concepts, because both of these abilities require gradual instructional support so that students can move from dependence to cognitive autonomy.

Several previous studies have attempted to examine the development of mathematics teaching materials that are oriented towards improving literacy and numeracy. A number of studies focused on the development of digital modules, the use of the *Realistic Mathematics Education* (RME), to the use of augmented reality in numeracy learning in elementary schools. At a higher level, a systematic review of 36 empirical articles also showed that the Problem-Based Learning model consistently had a positive impact on students' mathematical literacy abilities [6]. These studies make an important contribution in proving that contextualizing material by connecting mathematical concepts to real-life situations can increase students' cognitive engagement and enthusiasm for learning. For example, research on the development of digital modules generally uses a single learning outcome test instrument without an initial needs analysis that directly involves students' perceptions, while RME-based studies focus more on improving understanding of concepts at the secondary level and rarely target simultaneous literacy-numeracy slices in elementary schools. A recent umbrella study of 44 experimental studies of elementary school mathematics learning also confirmed that effective learning requires a structured alternation between classical and individual learning accompanied by gradual guidance, but the study has not specifically targeted the intersection between literacy and numeracy [7]. This kind of methodological limitation is the main gap that this study tries to fill. However, most of the existing research has not explicitly integrated the *scaffolding* as a comprehensive design framework in printed teaching materials, especially those specifically designed to simultaneously stimulate literacy and numeracy skills at the elementary school level. Furthermore, studies examining the need (*need analysis*) Teaching Material Design Based *scaffolding* by involving the perspective of teachers and students directly is still very limited in Indonesian and international literature. Gaps (*Research gap*) This is the starting point of this research. Referring to these gaps, this study specifically fills two gaps that have not been touched simultaneously in the previous literature, namely the integration of multi-level scaffolding design into printed teaching materials and the direct involvement of students' and teachers' perspectives in the needs analysis stage, rather than just the developer's normative assumptions.

The novelty or novelty of this research lies in the teaching material design approach that integrally combines three main dimensions: (1) *thematic-based content* that contains short narratives loaded with mathematical data as a trigger for literacy skills; (2) the implementation *of a multi-level* scaffolding technique from *Level 1* (high assist) to *Level 3* (independent) that allows students to gradually transition from dependency to learning autonomy; and (3) an adaptive visual component with a 40:60 image-text ratio designed to reduce students' cognitive load while maintaining the readability of instruction. This kind of integrated approach has not been comprehensively found in previous studies, so this research is expected to be able to fill this gap by making significant conceptual and practical contributions.

Based on the description above, the formulation of this research problem is: how to design the need for scaffolding-based mathematics teaching materials that are able to stimulate literacy and numeracy of elementary school students? Specifically, this study aims to: (1) identify the profile of students' initial literacy and numeracy abilities as the basis for needs analysis; (2) mapping the preferences of teaching material features from the perspective of students and teachers' constraints in designing literacy-numeracy-oriented learning; and (3) produce design specifications for mathematics teaching materials based on *scaffolding techniques* that are theoretically and empirically validated. The benefits of this research include two aspects: theoretically, this research contributes to the development of a teaching material design framework that integrates ZPD theory with mathematical literacy principles; Practically, the results of the research are expected to be a reference for teachers and curriculum developers in designing mathematics teaching materials that are more responsive, contextual, and oriented towards the sustainable development of literacy-numeracy competencies of elementary school students.

Considering the overall conditions that have been described, the needs analysis research (*need analysis*) is a methodological step that cannot be skipped until a teaching material product is designed and developed. Without a strong foundation for needs analysis, the development of teaching materials risks producing products that look technically attractive but do not really answer the cognitive problems experienced by students in the field. Ningrum, Widodo, and Fonda (2025) in a needs analysis study conducted at SD Muhammadiyah 2 Babat found that the teaching materials currently available are not able to improve students' numeracy literacy skills, where 42% of students are in the low category and 8% are even in the very low category. Furthermore, the study revealed that students really like colorful, visual, and interactive teaching materials that have not been accommodated by conventional package books or existing workbooks. These findings reinforce the argument that the design of teaching materials should be built on a foundation of empirical data that reflects the real needs of students, rather than mere normative pedagogical assumptions [8]. The findings of Ningrum, Widodo, and Fonda reinforce the urgency of this research to continue the needs analysis to a more detailed stage, namely mapping specifically the profile of students' initial abilities and the preferences of teaching material features

as a direct basis for the formulation of design specifications at the Design stage in 4D models [8].

Starting from all the arguments and empirical evidence that have been presented, this research is present as a systematic effort to fill the gaps that have not been comprehensively touched in the literature of basic mathematics education in Indonesia. By combining the analysis of students' initial literacy-numeracy ability profiles, the mapping of teaching material feature preferences from the student's perspective, and the simultaneous identification of teachers' constraints in one integrated research framework, this study is expected to produce a scaffolding-based mathematics teaching material design specification that is not only responsive to students' cognitive needs, but also realistic to be implemented in elementary school classroom conditions indeed. The contribution of this research is ultimately not just to produce a description of the problem, but to offer a *blueprint for* instructional design that can be immediately followed up to the development and validation stage of the product within the framework of Thiagarajan's 4D model on an ongoing basis.

2. Method

2.1. Research design

This study uses a quantitative descriptive approach (*Quantitative Descriptive*) as its main methodological framework. The selection of this design is based on the consideration that the main purpose of the research is to map the real conditions in the field, especially the profile of students' literacy and numeracy abilities as well as the needs of teaching materials from the perspective of teachers and students in a systematic, measurable, and can be represented in the form of meaningful numerical data. In the context of teaching material development, quantitative descriptive research serves as a solid empirical foundation before entering the product design and production stage. The development procedure referred to in this study uses a 4D model (*Four-D Model*) developed by Thiagarajan, Semmel, and Semmel, which consists of four sequential stages: *Define* (definition), *Design* (planning), *Develop* (development), and *Disseminate* (dissemination). This research is specifically in the first stage, namely *Define*, which includes a needs analysis (*need analysis*) as the basis for the preparation of teaching material specifications [9]. The limitation of this research is only at the Define stage with the consideration that the formulation of accurate design specifications requires adequate field needs data as a foundation, before resources are allocated to the product design and development stage. The implication is that the output of this research is in the form of design specifications, not teaching material products that have been tested for effectiveness, so that the Design, Develop, and Disseminate stage becomes a follow-up research agenda. This kind of limitation of research scope at the needs analysis stage is also common in other instructional design research that uses a phased development model, such as Discovery Learning learning design research which also limits its scope only to the analysis and design stages before entering the development stage [10]. As a completeness of the research design, the variables and indicators measured in the Define stage are systematically identified as follows: (1) learning conditions, with indicators of teacher-centered learning percentage and procedural question percentage; (2) students' literacy-numeracy skills, with indicators of the ability to find text information, interpret graphs/tables, use symbols and algorithms, and reason and simplify complex problems; (3) the preference of teaching material features, with indicators of support for visual integration, simple language, stepwise guidance (scaffolding), and local contexts; and (4) teacher constraints, with indicators of the availability of time for the preparation of narrative questions and the availability of literacy-numeracy learning resources. These four variables are synthesized into the teaching material design specifications as presented in section 3.5. This approach was chosen because it has proven to be effective in producing instructional products that are responsive to the needs of the local context while being scientifically validated [11].

2.2. Research Setting and Participants

This research was carried out at SD Muhammadiyah 2 Babat in September 2024. This location was deliberately chosen based on preliminary observation findings that indicate a significant gap between students' literacy-numeracy achievement and the availability of adequate teaching materials. The research subjects consisted of 30 students in class V and 2 mathematics teachers who were on duty at the school. The thirty students consisted of 16 male students and 14 female students aged 10-11 years, with initial academic abilities that varied based on the previous semester's report card scores, ranging from low to medium categories, so that the subject profile represented the heterogeneous class conditions commonly found in elementary schools. The two mathematics teachers who were the subject of the study had more than five years of teaching experience and were permanent teachers of mathematics subjects in grade V in the

current school year. The determination of the subject is carried out through the technique *purposive sampling*, which is a sampling strategy that is based on certain considerations and criteria relevant to the research objective, not solely on the basis of random chance [12]. In this case, grade V students were chosen because they were at the right stage of cognitive development to explore literacy and numeracy skills in the context of multi-level mathematical problems, while the teachers chosen were those who were directly involved in the daily mathematics learning process. The use of media in this school is still dominated by government package books (print) and conventional Student Worksheets (LKS) that have not optimally integrated literacy and numeracy dimensions into their design.

2.3. Development Procedure

The procedure of this study follows the flow of *the Define* stage in the 4D model, which is divided into several sub-analysis activities, namely:

1. *Front-end analysis*, to identify gaps between existing learning conditions and expected conditions;
2. *Learner analysis*, to understand the characteristics, initial ability level, and learning needs of students;
3. *Task analysis*, to map mathematical competencies and subcompetencies relevant to literacy and numeracy skills; and
4. *Concept analysis*, to identify core mathematical concepts that need to be contained in teaching materials.

All findings from this analysis stage are then synthesized to produce a teaching material design specification that includes a theme-based content structure (*thematic-based content*), engineering implementation *scaffolding* multi-level (Level 1 to Level 3), as well as adaptive visual elements. This stage is in line with the principles of teaching material development that emphasizes the importance of content suitability with the real needs and learning context of students as the foundation for effective product design [3].

The overall flow of the research procedure, from initial observation to the synthesis of design specifications, is presented in the following Fig. 1.

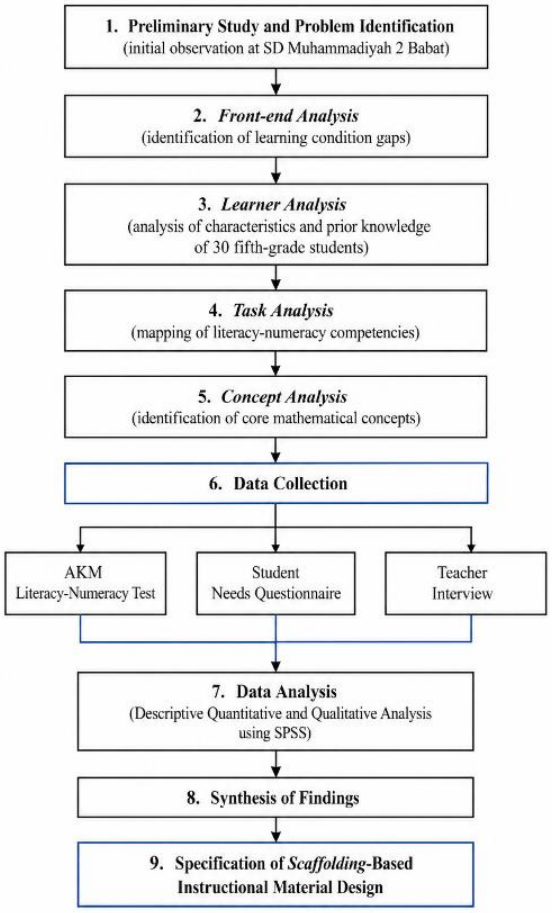


Fig. 1. Flow of Define Stage Research Procedures in 4D Models

2.4. Instruments and Data Collection

Data collection in this study was carried out through three main instruments that complement each other. First, *Numeracy Literacy Ability Test* which consists of five description questions based on the AKM format (*Minimum Competency Assessment*), designed to measure three aspects of student cognitive in an integrated manner: comprehension (*Understanding*), applications (*Application*), and reasoning (*Reasoning*). Second, *Structured Interview Guidelines* Aimed at two mathematics teachers, it covers four main aspects: the availability and problems of learning media, curriculum implementation, student characteristics, and resources available in schools. Third, *Assessing the Needs of Students* which contains five aspects, including interest in mathematics learning, perception of material difficulties, media availability, learning media preferences, and interest in LKPD. This questionnaire instrument was adapted and modified from the instrument developed by Wati, Yuniawatika, and Murdiyah to adapt it to the context of research focusing on literacy and numeracy [13]. Similar studies using a combination of interviews, observations, and questionnaires have shown that

triangulation of these instruments is able to produce a more comprehensive and accurate picture of needs than the use of a single instrument [11,12].

The literacy-numeracy ability test instrument has gone through a content validity test by two lecturers who are experts in mathematics education before being used, following the content validation procedure as explained by [14], with the results of all question items declared valid and suitable for use. The reliability of the instrument is tested using the Alpha Cronbach coefficient [15], with results in the reliable category. The student needs questionnaire instrument adapted from Wati, Yuniawatika, and Murdiyah was also adjusted to the literacy-numeracy context through expert analysis before being disseminated. Data triangulation was carried out by cross-comparing three data sources, namely the results of the student ability test, the results of the student needs questionnaire, and the results of teacher interviews, to ensure the consistency of the findings before they were integrated into the synthesis of the design specifications in section 3.5.

2.5. Data Analysis

Data obtained from the numeracy literacy ability test were analyzed in a quantitative descriptive manner using SPSS software (*Statistical Package for the Social Sciences*). The results of the analysis are presented in the form of percentage achievement on each cognitive aspect and then categorized into five levels: very low, low, medium, high, and very high, based on the score interval that has been set. Interview data with teachers were analyzed qualitatively descriptively to identify patterns of constraints, availability of learning resources, and expectations for the development of teaching materials. Meanwhile, student questionnaire data was analyzed using descriptive statistics in the form of frequency and percentage distributions to obtain a comprehensive picture of the preferences of teaching material features. The integration of the results from these three data sources is then used as a basis for formulating design specifications for mathematics-based teaching materials *scaffolding* which is literacy-numeracy-oriented. This kind of integrated analysis approach is relevant and consistent with instructional development studies that combine quantitative and qualitative data to obtain a stronger design foundation [5,16].

The determination of five achievement categories, namely very low, low, medium, high, and very high, refers to the percentage score interval commonly used in the categorization of educational research results [17], i.e. $0-20\%$ very low, $21-40\%$ low, $41-60\%$ moderate, $61-80\%$ high, and $81-100\%$ very high. Quantitative data from tests and questionnaires are processed first through SPSS to produce a percentage score per indicator, then the results are interpreted together with qualitative data from teacher interviews through the process of data reduction, grouping of constraint themes, and drawing conclusions, so that the two types of data complement each other in formulating final design specifications.

3. Results and discussion

This section presents the findings obtained from the *need analysis stage* carried out in the primary schools of the research target. Data was collected through three main instruments, namely early learning observation, literacy and numeracy ability tests based on the AKM format, and questionnaires for teaching material needs aimed at students and teachers. All data are presented sequentially, starting from the observed learning conditions, the profile of students' initial abilities, to the design specifications of teaching material needs formulated based on the synthesis of field findings.

3.1. Early Learning Conditions

Before presenting student ability data, it is important to first understand the learning context behind the low literacy and numeracy achievement in elementary schools. Initial observations conducted on 30 students and two mathematics teachers showed that the learning that took place was still far from an approach oriented towards the development of higher-level thinking skills. The media used daily is limited to government package books in print format and conventional Student Worksheets (LKS), two types of learning resources that have dominated the classroom without meaningful design updates. This condition creates a learning environment that tends to be passive and monotonous, where students do not get enough opportunities to explore mathematical concepts in meaningful and contextual situations.

Table 1
Results of Initial Observation of Learning Conditions

Observation Indicators	Percentage
Teacher-centered learning	68%
Mathematical problems are procedural (straight to the formula)	55%

Note: based on observations of 30 students and 2 teachers during three learning sessions, September 2024.

The two findings in Table 1 reinforce each other: the dominance of one-way learning limits students' reasoning and interpretation space, which is

precisely the core of mathematical literacy competencies, while questions that directly lead to formulas without reading processes and interpreting context make students' learning experiences isolated from the real world, so that their literacy is never truly trained in authentic mathematical situations. The percentage in Table 1 is calculated from the proportion of learning episodes that show a one-way pattern or procedural problem of the overall episodes observed during the three classroom observation sessions.

3.2. Student Literacy and Numeracy Ability Profile

Referring to the initial observation data that illustrates the lack of literacy and numeracy stimulation in learning, the next step is to measure empirically the extent of the impact of these conditions on student competency achievement. The *pre-analysis* data on literacy and numeracy ability was obtained from *pre-test* scores and previous report card scores, then summarized in four main indicators that included literacy and numeracy dimensions proportionally. These four indicators are designed to provide a comprehensive picture of a student's ability profile, not just a single score that simplifies the true complexity of competencies.

Table 2
Student Literacy and Numeracy Ability Data (Pre-Analysis)

Literacy and Numeracy Indicators	Percentage Achievement	Categories
Literacy: Finding information in the text about the story	52%	Medium
Literacy: Interpreting the meaning of a chart or table	45%	Medium
Numeracy: Using symbols and algorithms	68%	Height
Numeracy: Reasoning and simplifying complex problems	55%	Medium

Note: based on the test score of five questions of the description of the AKM format (maximum score of 100 per aspect) and the previous report card score; Category refers to the score interval in subchapter 2.5.

The data in Table 2 reveal a striking gap between students' procedural abilities and high mathematical thinking skills: high-category achievement only appears in indicators of symbol and algorithm use, while once the problem shifts to a realm that requires text comprehension and complex reasoning, student achievement immediately drops to the medium category. This pattern consistently shows that students' greatest weakness is not in their mastery of computational mechanisms, but in their ability to read, interpret, and reason mathematically in more complex contexts, a gap that can only be closed through teaching materials that explicitly integrate the literacy dimension into every aspect of mathematics learning. This pattern is consistent with the views of Rezat, Malik, and Leifeld [3] that linguistic understanding and logical reasoning work as a cognitive unit in mathematics, so that weaknesses in the literacy aspect have a direct impact on numeracy achievement even though students' procedural abilities are adequate.

3.3.Analysis of the Need for Teaching Materials

After obtaining a clear picture of the student's initial ability profile, this study further explores students' perspectives on the features of teaching materials that are considered ideal and best suited to their needs. The questionnaire data on the need for teaching materials distributed to 30 students produced findings that are very relevant as a reference in designing teaching material products. This questionnaire covers five aspects, but the most informative for design purposes is the preference of teaching material features, the results of which are summarized in the following table.

Table 3
Teaching Material Feature Preferences from a Student's Perspective

Desired Features	Percentage Agree
Visual integration (images/infographics)	83%
Simple use of language	77%
Step-by-step guide (*scaffolding*)	88%
Material relationship to local culture/context	70%

Table 3 presents significant findings from an instructional design perspective. The highest support for step-by-step guidance affirms that scaffolding is not just a theoretical pedagogical option, but a real response to students' cognitive needs that have been neglected by conventional teaching materials. Strong support for visual integration suggests the need for dual representation to reduce cognitive burden, while preference for simple language and local contexts completes the picture that students need teaching materials that are mathematically accurate as well as linguistically friendly and culturally relevant. This preference for gradual guidance is in line with the ZPD Vygotsky principle which states that students need external help to achieve competencies that cannot yet be achieved independently, while the high preference for visual integration is in line with cognitive load theory that places visual-text dual representation as a strategy to reduce the working memory load of elementary school-age students.

3.4. Teachers' Obstacles in Developing Numeracy Literacy Learning

In addition to the students' perspective, an in-depth interview with two mathematics teachers revealed the real obstacles faced in terms of educators. Two main barriers were identified consistently in the interview. First, teachers have difficulty finding problems that are able to train students' reasoning skills without looking boring, a design challenge that requires high creativity and a deep understanding of mathematical contextualization. One of the teachers said this directly during the interview: "Sometimes I have thought about making an interesting story, but once I try to write it, I play it myself, and finally I go back to the usual question because it is faster." Second, compiling narrative-type questions takes much longer than compiling ordinary counting questions, so that in conditions of a full teaching load, teachers tend to choose the easiest way by using procedural questions available in the package book.

The second teacher added a similar problem in terms of time: "If it's a regular count, I can prepare ten questions in an hour. When it comes to stories that have context, sometimes it takes half an hour alone, while my teaching hours are full." These two constraints together create a systemic pitfall: teachers are aware of the importance of numeracy literacy, but do not have enough time and resources to make it a reality in daily learning practice. These findings are consistent with the results of Musyrifah, Dwirahayu, and Satriawati [18] who also found that the limited time and resources of teachers are the main obstacles in providing quality literacy-numeracy teaching materials, thus strengthening the argument that the teaching materials produced by this research need to be designed to ease, not increase, the burden of preparing questions for teachers.

3.5.Product Design Specifications Teaching Materials

Based on a comprehensive synthesis of all observation, test, questionnaire, and interview data above, this study succeeded in formulating the design specifications of scaffolding-based mathematics teaching materials presented in the following table. This specification is designed to directly address any gaps identified, ranging from students' low contextual literacy to the limitations teachers face in providing high-quality questions.

Table 4 shows that the proposed design of teaching materials does not stand on a single principle, but rather is a careful integration of several mutually reinforcing instructional dimensions. The placement of short articles containing mathematical data at the beginning of each chapter serves a dual purpose: it trains reading and finding information (literacy), while also introducing the context that will be the frame for the next numeracy problems.

Table 4

Product Design Specifications of Proposed Teaching Materials

Design Components	Description
Content structure	*Thematic-based*; each chapter opens with a short article of 200–300 words that contains contextual mathematical data
Scaffolding Level 1 (high relief)	The questions are equipped with "What to know" and "What to ask" tables that are already half filled
Scaffolding Level 2 (moderate relief)	The question is accompanied by a *hint* or hint in the form of a light icon next to the question
Scaffolding Level 3 (self-contained)	Open-ended questions without assistance to test numeracy independence
Visual–text ratio	40:60 to reduce cognitive load while reading
Elements of technology	Addition of *a QR Code* that leads to a short animated video related to the concept discussed

The three levels are designed to allow each student regardless of their ability level to still be able to participate meaningfully in the learning process. Students who still need a lot of guidance can start from Level 1, then gradually transition to Level 3 as their confidence and competence increase. The 40:60 visual-text ratio was chosen based on the consideration that overly dominant visual involvement can distract from mathematical substance, while overly dense text can create an excessive cognitive burden for elementary-age students. Attendance *Powered by E-Mail* As a bridge between print teaching materials and digital content, it provides a dimension of interactivity that has been absent from conventional teaching materials, while answering the need for dynamic visual representations for mathematical concepts that are difficult to visualize in a static format. Support for the integration of such technological elements is also in line with the finding that problem-based learning assisted by interactive visual media such as GeoGebra has been shown to significantly improve students' mathematical problem-solving abilities compared to conventional learning [19].

These relationships can be traced directly from the need analysis data: the structure of the thematic content answers the low achievement of literacy in finding information in Table 2; a three-level scaffolding system answers the highest student support for the step-by-step guidance in Table 3; The 40:60 visual-text ratio answers visual integration preferences; and the QR Code feature answers the need for dynamic representation that conventional printed teaching materials cannot facilitate. Compared to literacy-numeracy teaching material products in previous research, such as Musyrifah, Dwirahayu, and Satriawati [18]which focuses on madrasah ibtidaiyah teachers without multi-storey scaffolding features, and Inafah and

Saputro [20] which is based on interactive multimedia without a printed thematic structure, the specification in this study offers the integration of all three elements at once in a single design framework. Practically, teachers can use the "What knows" and "What is asked" structures at Level 1 as ready-to-use templates when compiling narrative questions, thus directly answering the teacher's time constraints described in section 3.4.

3.6. Product Validation Plan

It should be emphasized that this section is not the result of research that has been carried out, but a follow-up research plan that will be taken at the Develop stage in the 4D model. Validation will be carried out by experts in three different dimensions: validation of material that focuses on the accuracy of mathematical concepts and the depth of literacy questions; language validation that emphasizes the readability of instructions for students; and media validation that includes aesthetic aspects, ease of use, and functionality of additional features such as *QR Codes*. This three-dimensional validation framework is designed to ensure that the resulting final product is not only superior in content, but also visually feasible and can be used independently by students without the need for intensive mentoring from teachers at all times.

3.7.Discussion

The findings of this study as a whole provide a comprehensive picture of the real conditions of mathematics learning in elementary schools, especially in relation to students' literacy and numeracy abilities and the availability of teaching materials that support them. The following discussion reviews in depth each key finding by linking it to the theoretical and empirical evidence of relevant previous studies.

The first finding related to the dominance of one-way learning by 68% and the high percentage of procedural questions (55%) confirm that the existing learning environment has not been able to create conducive conditions for the development of students' literacy and numeracy skills. Conditions *teacher-centered* This kind of directly suppresses students' cognitive exploration space, especially in terms of reading mathematical texts, interpreting context, and formulating solving strategies independently. This is in line with the arguments put forward by Tegeh, Astawan, Sudiana, and Kristiantari who found that the low creativity of teachers in designing meaningful learning experiences is one of the root causes of weak literacy and numeracy of students in elementary schools. In their study, the application of a learning model that encourages students' active engagement was combined with *metacognitive scaffolding* proven to be able to raise the average scientific literacy score to 77.67 and numeracy ability to 75.37. These findings confirm that the paradigm shift in learning from a teacher-centered to a more interactive and structured approach is a fundamental prerequisite before talking about the development of any teaching materials [21]. These findings are also in line with the synthesis of 44 experimental studies by [7], which concludes that effective elementary school mathematics learning requires a structured alternation between classical, cooperative, and individual learning accompanied by gradual guidance, rather than just one-way material delivery.

The profile of students' literacy and numeracy abilities revealed in this study, where the ability to interpret graphs only reaches 45% and reasoning complex problems is at 55%, reflecting a pattern consistent with the findings of various previous studies. Setiyani, Waluya, Sukestiyarno, Cahyono, and Santi in their study of junior high school students found that the majority of students were not familiar with numeracy-type questions that were always preceded by contextual texts, so they tended to guess the answers without really understanding what was known and asked in the questions [22]. This phenomenon occurs because for many years students have been accustomed to facing problems that directly require calculation operations, without practicing reading skills and interpreting mathematical situations first. Furthermore, Santi, Setiyani, Waluya, Sukestiyarno, and Cahyono, who studied the numeracy skills of junior high school students in Cirebon, emphasized that students need reminders of prerequisite materials and guidance in understanding the structure of text-based questions, a need that can only be met if the teaching materials are designed explicitly with features *scaffolding* structured [23]. This finding is also in line with the results of Fildzah and Masriyah's analysis which identified that students' mistakes in solving questions equivalent to numeracy AKM include errors in reading, comprehension, transformation, process skills, to writing conclusions and all types of errors can be minimized through giving *scaffolding* in the form of planned questions, instructions, reminders, and directions [24].

The finding that 88% of students stated that they urgently needed step-by-step guidance in teaching materials is a strong empirical validation of the relevance of the technique *scaffolding* as a core component of the proposed product design. This support is not just an aesthetic preference, but rather a reflection of real cognitive needs. Dassa, Hidayah, Mansyur, Hafsari, and Ramlan in their qualitative research found that the *scaffolding* given to students should be dynamically adjusted to the actual level of ability of each individual: students with medium abilities need *scaffolding* in the form of subtle monitoring and evaluation, while low-ability students need more explicit and directive direction. This principle of adaptivity is the main basis why the design of teaching materials in this study adopts a *scaffolding* three levels from Level 1 which provides high assistance to Level 3 which demands full independence so that each student can find an entry point that corresponds to his or her proximal development zone [25]. In an earlier context, Bitew, Wondim, and Bewuket also found that teachers who applied the *scaffolding* Planned modeling, instruction, and gradual reinforcement can support children's literacy and numeracy development more effectively than those who teach without a clear guidance framework [26].

Students' preference for visual integration (83%) and

the use of simple language (77%) provide very concrete guidance for the design of teaching materials. Inafah and Saputro in research on interactive multimedia development *scaffolding* It found that media that combined visual elements with a tiered tutoring structure received a very positive response from students with an eligibility score from subject matter experts reaching 95% and scores from large groups reaching 93% indicating that the integration of visual representation into the framework *scaffolding* not just to make the display more attractive, but to substantively help students build a more gradual and meaningful understanding of concepts [20]. This is reinforced by the findings of Ramadhani, Agung, Izzania, Sari, and Supriatna who concluded that elementary school students' numeracy skills develop optimally when learning encourages conceptual understanding, reflective reasoning, and the application of strategies in a three-dimensional real, real, three-dimensional context, all of which can be facilitated through teaching materials that are rich in visual representations and relevant contextual narratives [27].

The obstacles faced by teachers in compiling narrative questions and finding learning resources oriented to numeracy literacy also strengthen the need for teaching material products that not only function as a source of student learning, but also as a pedagogical guide for teachers. Musyrifah, Dwirahayu, and Satriawati developed special mathematics teaching materials for madrasah ibtidaiyah teachers using a 4D model and found that the resulting product was considered feasible by experts (76.73) and practitioners (76.06), although it still needed improvement in terms of clarity of concept explanations and implementation of learning strategies. These findings underline that the development of effective teaching materials cannot be only student-oriented, but must also consider the needs and limitations of teachers as the main users in the classroom [18]. In line with this, Nurwahid, Ashar, and Awantagusnik emphasized that the successful implementation of numeracy-literacy-oriented learning strategies includes the use of *scaffolding* and realistic contextualization is highly dependent on the readiness of the education ecosystem that includes teacher understanding, availability of contextual resources, and adequate policy support [28,29]. Thus, the design specifications of the teaching materials produced in this study that integrate contextual narratives, *scaffolding* tiered visual elements, adaptive visual elements, and features *Powered by E-Mail* It is not only a response to the needs of students, but also a structural answer to the systemic limitations that have been hindering teachers in presenting meaningful, contextual, and literacy-numeracy-oriented mathematics learning in elementary schools [30,31].

Findings related to product validation plans in the three dimensions of material, language, and media also require a more in-depth discussion from a practical point of view. The development of quality teaching materials does not just stop at the specification design stage, but must go through a series of verification processes involving experts from various relevant areas of competence. Hopeman, Rahma, and Pradesa in their classroom action research found that the application of learning strategies *metacognitive-scaffolding* planned and structured to significantly improve the numeracy ability of grade III elementary school students, from the average *Pre-test* of 59.1 which was categorized as less to 70.2 in *Post-test* The second cycle which is categorized as good with the number of students who have not completed has been drastically reduced from 19 to only 3 students. This achievement is inseparable from the intervention design process based on careful needs analysis before implementation. These findings directly reinforce the urgency of this research in ensuring that every component of the teaching material is designed starting from the contextual narrative, the system *scaffolding* multi-level, until the visual elements have gone through a rigorous validation process before being tested on students, so that the impact produced is truly measurable and can be scientifically accounted for [32].

Overall, the synthesis between the field findings and the evidence from previous research in this discussion yields one major conclusion that cannot be ignored: the improvement of the literacy and numeracy skills of elementary school students will not be realized through a change in teaching methods alone, without the availability of teaching materials that are inherently designed to stimulate both abilities simultaneously and in a structured manner [33,34]. Rahmat proved that innovation in learning strategies and media, in this case, the model *Means Ends Analysis* based on Digital Literacy Cards is able to raise the value of *Post-test* The experimental class reached 80, far exceeding the control class which only scored 64.17, a difference large enough to confirm that targeted instructional design has a real and measurable impact on students' mathematical representation numeracy skills. This means that math-based teaching material products *scaffolding* proposed in this study is not just an administrative complement to the curriculum, but a pedagogical intervention that, if developed and implemented correctly, has the potential to be a catalyst for real change in an effort to improve the quality of mathematics learning in Indonesian elementary schools in a comprehensive and sustainable manner [35].

It should be emphasized that all the relationships described in this section are descriptive-correlative, not causal, because the design of quantitative descriptive research at the Define stage does not involve hypothesis tests or classical assumption tests that are commonly used in experimental or correlational designs. The purpose of this study is to map needs, not to test the influence of a treatment, so that the use of descriptive statistics in the form of percentages and score categorization is considered adequate and in accordance with these objectives. Theoretically, these findings strengthen the relevance of ZPD Vygotsky's theory in the context of mathematical literacy-numeracy in Indonesian elementary schools; In practical terms, these findings recommend that teachers begin to integrate short contextual narratives and step-by-step guidance into daily questions gradually, starting with Level 1 scaffolding as the easiest entry point to implement without the need for intensive training.

3.8. Research Limitations

This research has a number of limitations that need to be honestly acknowledged as a consideration for future researchers. First, the scope of the research subject which is limited to 30 students and 2 teachers in one school, namely SD Muhammadiyah 2 Babat, makes the generalization of findings cannot be done directly to the context of other elementary schools that have different characteristics, both in terms of socio-economic conditions, teacher qualifications, and student learning culture. The limitation of generalizations in a single case study like this is a methodological consequence prevalent in studies with limited subjects, as emphasized [36], so that the findings of this study are more appropriately understood as an in-depth portrait of one school context, rather than a generalization of the elementary school population at large. Second, this study only covers the *Define* in the 4D model of Thiagarajan, so that the design specifications of the resulting teaching materials have not passed the process of expert validation, readability tests, and empirical effectiveness tests in the field [37]. Thus, the conclusions drawn are still descriptive-analytical and cannot be used as causal evidence about the direct impact of the designed teaching materials on improving students' literacy and numeracy skills [38,39].

The next limitation relates to the data collection instruments used. The literacy-numeracy ability test developed in this study only consists of five description questions based on the AKM format, so that the range of measurable indicators does not fully represent the complexity of literacy and numeracy constructs as a whole [40-48]. In addition, student needs questionnaire data has the potential to contain *response bias* considering that elementary school-age students tend to provide answers that teachers or researchers consider desirable, rather than solely reflecting their real needs and preferences [48-55]. The limited time of data collection that was only carried out in one observation period was also a limiting factor that did not allow researchers to capture the dynamics of changing student needs longitudinally. Therefore, further research with a wider sample scope, more comprehensive instruments, and complete development stages to *disseminate* is highly recommended to produce a more validated and impactful teaching material product [56-59].

4. Conclusion

This needs analysis research answers the three objectives formulated in the introduction. Through a quantitative descriptive method at the Define 4D model stage involving 30 students and 2 teachers at SD Muhammadiyah 2 Babat, this study produced three main conclusions that are interrelated. First, the condition of mathematics learning, which is still dominated by a teacher-centered approach (68%) and procedural problems (55%), proved to be the root cause of low literacy and numeracy achievement of students, where the ability to interpret graphs only reached 45% and complex problem reasoning of 55% were both in the medium category, answering the first goal of the study. Second, needs analysis from the perspective of students revealed that multi-level scaffolding guidance received the highest support (88%), followed by visual integration (83%), simple language (77%), and local contextualization (70%), answering the second goal of the study. Third, the design specifications of the teaching materials produced include theme-based content, a three-level scaffolding system, a 40:60 visual-text ratio, and a QR Code feature, answering the three objectives of the research as well as being the main scientific contribution of this research, namely the teaching material design framework that explicitly integrates the ZPD theory with the principles of mathematical literacy, something that has not been comprehensively found in previous literacy-numeracy teaching material research.

Given the limitations of subject coverage in a single school as outlined in section 3.8, generalization of these findings needs to be done carefully and ideally revalidated in schools with different socio-economic characteristics and learning cultures before being widely applied.

The practical implications of this research were conveyed to three parties. For elementary school math teachers, these findings imply the need for a gradual shift from a procedural teaching approach to learning that integrates contextual texts and structured guidance, starting with the application of the "What knows" and "What is asked" formats to daily questions as the simplest steps. For the developer of teaching materials, the design specifications of the 40:60 visual-text ratio and the three-level scaffolding structure can be directly used as a technical reference for the preparation of modules. For education policy makers, the results of this study confirm the importance of providing teaching materials specifically designed to stimulate literacy and numeracy, not just generic package books, as a strategic investment in improving the quality of mathematics education in elementary schools.

As a direction of further research, considering that this research only includes the Define stage and has not gone through expert validity tests or field effectiveness tests, the next researcher needs to immediately follow up this specification to the Design stage to prepare a prototype of teaching materials, the Develop stage to validate material, language, and media experts as planned in section 3.6, as well as limited trials and empirical effectiveness tests on a wider and more diverse sample before entering the Disseminate stage.

CRediT authorship contribution statement

Iza Eka Ningrum: Conceptualization, Methodology, Software, Investigation, Formal analysis, Writing - original draft. Mochamad Ainul Yaqin: Supervision, Validation, Writing - review & editing. Ana: Supervision, Methodology, Validation. Khairul Umam: Resources, Data Curation,

Visualization. Korhan Cengiz: Formal analysis, Writing - review & editing.

Declaration of Competing Interest

The authors state that there are no known conflicts of financial interest or personal relationships that could influence the work reported in this paper.

Data availability

Data will be available upon request.

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