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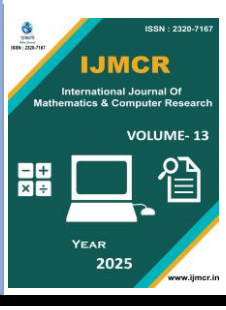

Designing the Mathematical Knowledge for Teaching Numeracy (MKT-N) Test for Secondary School Mathematics Teacher Prospective Students

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ABSTRACT

Several previous studies have discussed Mathematical Knowledge for Teaching (MKT) in general and still focus on the mathematical domain only. There have not been many studies that specifically develop MKT frameworks and instruments that focus on numeracy skills. In fact, numeracy is an essential skill that individuals must have in this century so numeracy is important to be taught in schools. In fact, there are still many teachers who have difficulty in teaching numeracy. Therefore, teachers need to have mathematical knowledge to teach numeracy or Mathematical Knowledge for Teaching Numeracy (MKT-N) from an early age. This research aims to design a test instrument that can measure Mathematical Knowledge for Teaching Numeracy (MKT-N) for prospective mathematics teachers at the secondary school level. The concept of MKT-N in this study was developed from the MKT framework which consists of six aspects and adjustments to the numeracy context according to the national framework. The preparation of the questions consists of three steps, namely analysis, design, and development. The results of the study were in the form of valid MKT-N questions based on expert validation with very good criteria (score 0.98). The design of this instrument is expected to be the basis for the development of standardized instruments to map the professional and pedagogic competencies of prospective mathematics teachers in teaching numeracy. Further research is needed to test the test instrument directly to obtain further validation.

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KEYWORDS: Mathematical Knowledge for Teaching (MKT), numeracy, prospective mathematics teacher

I. INTRODUCTION

Numeracy is a person's ability to use mathematical knowledge to solve practical problems in daily life. Numeracy is increasingly recognized as an essential skill in applying mathematical concepts to real-world situations and preparing students to face challenges in modern society[1], [2]. This ability is also one of the main indicators in measuring achievement Sustainable Development Goals (SDGs) formulated by the United Nations (UN). In the fourth goal of the SDGs, the United Nations emphasizes that the mastery of students' functional numeracy skills is one of the benchmarks for the quality of education [3]. Numeracy is considered an indicator of development because it focuses on developing critical thinking skills as well as the application of knowledge in real life [4]. These two abilities are crucial thinking skills in the 21st century era. However, the importance of numeracy is not balanced by adequate numeracy skills.

Low numeracy ability can be seen from the results Programme for International Student Assessment (PISA) with an average math score of about 374 from 2000 to 2022 [5], [6], [7], [8], [9], [10], [11]. In addition, difficulties in solving numeracy problems are also still encountered in students, including difficulties in understanding, transformation, procedures, and coding [12]. Therefore, the role of teachers is indispensable in teaching effective numeracy to students. According to [13] Teachers with a realistic view of numeracy education tend to cultivate better numeracy skills in students. However, research states that teachers' perceptions of numeracy are only limited to ordinary stories [14]. Numeracy is only limited to the school context just like mathematics is abstract. Even though numeracy is different from mathematics, where numeracy is a mathematical application in real life [15]. Teachers also consider that the difficulties experienced by students in solving numeracy problems are only procedural and

conceptual, not about the students' thinking process [16]. In fact, the teacher's ability to identify students' difficulties is very useful for developing effective learning strategies. This condition underlies the importance of teachers having knowledge to teach numeracy.

Teachers' knowledge in teaching numeracy is called Mathematical Knowledge for Teaching Numeracy (MKT-N). MKT-N is a theory developed from Mathematical Knowledge for Teaching (MKT) which was pioneered by [17] then modified by [18]. This theory consists of two main components, namely Subject Matter Knowledge (SMK) and Pedagogical Content Knowledge (PCK), where each component contains three aspects in it. Vocational schools consist of Common Content Knowledge (CCK), Specialize Content Knowledge (SCK), and Horizon Content Knowledge (HCK). While PCK contains Knowledge of Content and Student (KCS), Knowledge of Content and Teaching (KCT), and Knowledge of Content and Curriculum (KCC). Deep [19], these two components are one of the achievements of graduates in the Mathematics Education undergraduate study program as an effort to build professional teachers.

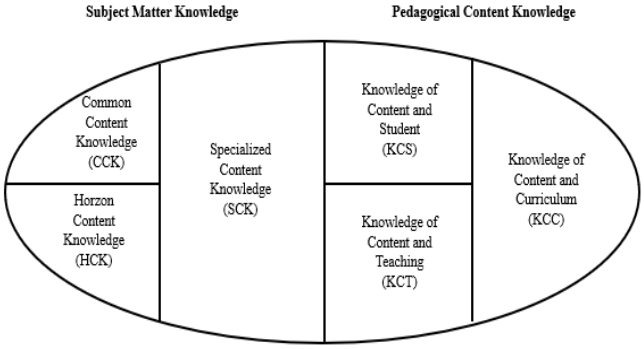

Figure 1. Domain Mathematical Knowledge for Teaching [18]

Teachers who are professional in teaching numeracy need to be prepared since they have undergone undergraduate education. The reason is, it is necessary to see whether the curriculum studied by prospective teachers is relevant to the needs in teaching numeracy. Moreover, the Teacher Competency Test (UKG) which was abolished since 2015 makes teachers' pedagogic and professional competence not measured holistically. This condition encourages an evaluation that is able to map the competence of prospective teachers in teaching numeracy.

Previous research still focused on MKT in general [20], [21], [22], [23], [24], [25] and MKT that focuses on the domain of mathematics [26], [27], [28], [29], [30], [31], [32], no one has discussed the MKT specifically related to numeracy. Therefore, this study aims to develop MKT-N test instruments for prospective mathematics teacher students.

II. METHOD

An easy way The type of research used is Research and Design (RnD) by adapting the initial three stages of the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) [33]. The development stage is carried out through three steps, namely Analysis, Design, and Development. Phase Analysis is carried out by identifying the content of the material by involving a comprehensive literature review of the theoretical framework of the MKT proposed by [18] and numeracy proposed by [34]. The review specifically focused on two main aspects: Subject Matter Knowledge (SMK) and Pedagogical Content Knowledge (PCK). The main objective of this analysis is to identify relevant indicators for use in the development of MKT-N test instruments.

Table 1. Mathematical Knowledge for Teaching Numeracy (MKT-N) Indicator

MKT-N	Indicators
CCK-N	Understand the basic concepts of mathematics in daily life.
SCK-N	Modifying math problems into numeracy problems. Analogizing mathematics in numeracy learning. Represent mathematical ideas in numeracy learning. Provide appropriate mathematical examples in numeracy learning.
HCK-N	Making math meaningful. Make connections to previous mathematical ideas.
KCS-N	Identify students' difficulties in numeracy learning.
KCT-N	Identify the instructional capabilities of the approach or method for a case.
KCC-N	Associate numeracy learning with the applicable curriculum. Determine the accuracy of the textbooks or media used in learning.

At the design stage, the researcher makes a grid of questions as a basis for compiling questions that include MKT aspects, numeracy aspects, indicators, question forms, and question numbers. The development stage is carried out by compiling a draft of question items, validating with the help of two experts in the field of mathematics education, and making improvements based on expert input so that a valid MKT-N test instrument is obtained. The research design stage is explained in Figure 1.

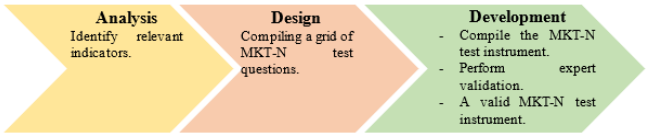

Figure 1. Research Design

Table 2. MKT-N Test Grid

Aspects of MKT-N	Indicators	Question Number
CCK-N	Understand the concepts of median, mean, and mode in their application in daily life in socio-cultural contexts.	1
	Grouping rectangular flat buildings based on the hierarchical properties of the quadrilateral in its application in the personal context.	2
	Understand the nature of zeros in a socio-cultural context.	3
SCK-N	Represent the mathematical patterns formed from a case in a socio-cultural context.	4
	Represent the root meaning of the square equation of a case in a personal context.	5
	Modify math problems in number patterns and object configurations in numeracy problems.	6
	Making an analogy from a graphic into the most appropriate personal narrative.	7
HCK-N	Determine the mathematics topics contained in daily life.	8
	Making the best suggestions for matrix learning meaningful.	9
	Create a sequence of previous math topics in algebraic content.	10
KCS-N	Analyze the general difficulties that arise from students' answers in a particular case.	11, 12, 13
KCT-N	Determine the most appropriate course of action to teach the difference between the median and mean in a personal context.	14
	Determine the best learning plan to teach elevation angles from a personal context.	15
	Determine the most appropriate approach to numeracy learning to teach integral volumes with partitions.	16
	Determine the most appropriate approach to numeracy learning to teach the concept of geometry transformation.	17
KCC-N	Determine the best numeracy learning strategies by integrating STEM approaches.	18
	Determine numeracy problems with excess and lack of data according to the needs of the curriculum.	19
	Determine the best numeracy learning actions by integrating technology.	20

To determine the validation of questions from experts, it is done by recapitulating validity assessment data into a table for each validator, determining the average scores of both validators, and categorizing the averages of all aspects of expert assessment into the following categories [35]. If the value is in the minimum accepted category, then the researcher proceeds to the next stage.

Table 1. Expert Rating Categories based on Average per Item

Average	Category
$\bar{x} \geq 0{,}8$	Valid
$0{,}6 \leq \bar{x} < 0{,}8$	Revision
$\bar{x} < 0{,}6$	Elimination

Table 2.
Expert Rating Categories by Total Average

Average	Category
$\bar{x} \geq 0{,}9$	Excellent
$0{,}8 \leq \bar{x} < 0{,}9$	Accepted
$\bar{x} < 0{,}8$	Need to Revise the Instrument

III. RESULT AND DISCUSSION

This research aims to develop a test instrument that represents Mathematical Knowledge for Teaching Numeracy (MKT-N) for prospective mathematics teacher students. This is based on the initial analysis stage, that numeracy has become a focus in national assessment policies. However, the mathematics teacher education curriculum tends to still be centered on mastering conventional mathematics content without explicitly preparing prospective teachers to teach numeracy in a contextual and meaningful way. This condition shows that there is a gap between the demands of the national education policy and the pedagogical readiness of prospective teachers. Therefore, the development of the MKT-N instrument in this study not only aims to map the competence of prospective teachers in teaching numeracy, but also provides relevant learning resources in equipping prospective teachers to face learning challenges.

The development of MKT-N questions refers to the conceptual framework of MKT developed by [18]. Based on

information obtained from several literature that has been reviewed by researchers, there are six aspects of MKT shown in Figure 2. While the numeracy aspect is based on Framework Minimum Competency Assessment (AKM) which consists of content including numbers, algebra, geometry and measurement, as well as data and uncertainty; The context includes personal, socio-cultural, and scientific, and the cognitive level includes understanding, application, and reasoning [34].

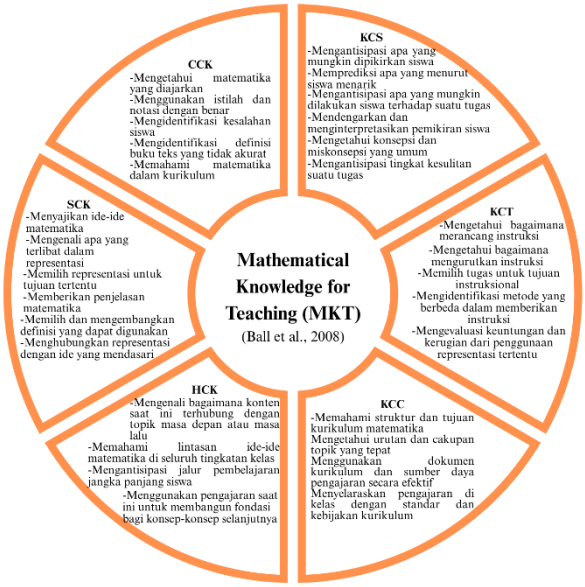

Figure 2. Aspects of Mathematical Knowledge for Teaching (MKT)

The researcher compiled MKT-N questions for high school mathematics teacher candidates consisting of 20 questions. The questions are divided into two sub-sections, namely 10 questions Subject Matter Knowledge (SMK) with the form of ordinary multiple choice and 10 questions Pedagogical Content Knowledge (PCK) with a multiple-choice form of the model Situational Judgment Test (SJT). Each question uses a context that is a characteristic of numeracy. The use of a wide context is important so that prospective mathematics teachers can recognize the meaning of mathematics in daily life. The information obtained by the researcher at the analysis stage is used as a guide in compiling a grid of questions carried out at the design stage. The preparation of the question grid is important because it can help researchers in compiling questions according to the specified criteria [36].

In the question grid, the researcher designed 3-4 questions on each aspect of MKT. Among the 20 questions designed, there were 4 number domain problems, 5 algebraic domain problems, 7 geometry and measurement problems, and 7 data and uncertainty domain problems. The context used is also diverse, there are 11 questions with a personal context, 10 questions with a socio-cultural context, and 9 questions with a scientific context. As for the distribution of cognitive levels, it includes 9 comprehension questions, 11 application questions, and 10 reasoning questions. The correct question in the multiple choice gets a score of 1, while the SJT question has a score level of 1 "Not Suitable", 2 "Not Suitable", 3 "Fairly Suitable", 4 "Suitable", and 5 "Very Suitable". Based on the design stage, the researcher carried out the development stage by compiling 20 MKT-N questions guided by the question grid so that a draft question 1 was obtained. At this stage, expert validation is also carried out by asking two validators in the field of mathematics education to conduct assessments and inputs related to the draft question 1. The validation of the draft question 1 is shown in Table 2.

Table 2. Data Analysis of Validation Results

Component	Criteria Number	Average of each component
Content and Materials	1-3	0,97
Language	4-7	0,98
Answer Selection Preparation Techniques	8-14	0,98
Eligibility and Relevance	15-16	1
Total Average Expert Validation		**0,98**

The assessment from the expert validation obtained a score of 0.98 with the category of very good so that the test instrument is suitable for use. Examples of improvements and suggestions for some questions are presented in Table 3.

Table 3. Revision of Draft Question 1

Number	Before Revision	After Revision
1	In a social activity, students are asked to write numbers on cards to be distributed randomly to participants in a row-and-march competition. Cards containing even numbers will enter row A, while odd numbers will enter row B. One of the students receives a card with the number 0 written on it and	In a social activity, students are asked to write numbers on cards to be distributed randomly to participants in a row-and-march competition. Cards containing even numbers will enter row A, while odd numbers will enter row B. Ayu receives cards with the number 0 written on them and has difficulty determining the rank of her group.

	has difficulty determining the row of his group. He heard some students say that 0 is a "positive number", while others say "a negative number". Based on that context, which statement is true about the number 0? A. 0 is an odd number, so it goes to row B. B. 0 is not a neutral number (not even and odd), so there is no need to follow the line. C. 0 is an even number, so it goes in line A. D. 0 is a positive and even number, so enter row A. E. 0 is a positive and neutral number (not even and odd), so there is no need to get in the queue. **Note:** The context of the question must be usable, so it must be integrated in the answer choice.	Based on this context, which statement is correct? A. Ayu will be in the A line. B. Ayu will enter the B line. C. Ayu will enter the A and B rows. D. Ayu doesn't follow any line. E. Feel free to enter any line.
8	The formula to find the roots of quadratic equations is divided into 3, namely: (1) factoring; (2) the quadratic formula, i.e. $x_{12} = \frac{-b \pm \sqrt{b^2-4ac}}{2a}$; and (3) the perfect square. However, most are still misrepresented in representing the meaning of the root of the quadratic equation especially in the context of real-life problems. "A football player kicks the ball by forming a parabolic trajectory. The height of the ball in t seconds is formulated in the equation $h(t) = -5t^2 + 20t$" That is why which is the most appropriate representation to understand the meaning of the roots of the equation of the problem? A. The roots of the quadratic equation show the time the ball was on the ground. B. The roots of the quadratic equation show the time of the ball at a certain height. C. The roots of the quadratic equation show the height of the ball when t=0 D. The roots of the quadratic equation show the height of the ball when t=4 E. The roots of the quadratic equation show the height of the ball at t=0 or t=4 **Note:** The explanation at the beginning is not working, it is better to omit.	"A football player kicks the ball by forming a parabolic trajectory. The height of the ball in t seconds is formulated in the equation $h(t) = -5t^2 + 20t$" That is why which statement is the most appropriate to understand the meaning of the root equations of the problem? A. The roots of the quadratic equation show the time when the ball is on the ground. B. The roots of the quadratic equation show the time of the ball at a certain height. C. The roots of the quadratic equation show the height of the ball when t=0 D. The roots of the quadratic equation show the height of the ball when t=4 E. The roots of the quadratic equation show the height of the ball at t=0 or t=4
15	A junior high school mathematics teacher conducted a diagnostic test on 30 grade VIII students. The results showed that 65% of students had difficulty determining sequential pairs (x,y) of function rules, and 70% of students could not draw graphs of simple functions such as f(x)=2x+1. To reduce this difficulty, the teacher planned the order of delivery of the material. Which sequence is most effective for reducing student difficulty? A. Number Pattern – PLSV – Function – Cartesian Coordinates – Relationships	A junior high school math teacher conducted a diagnostic test at the beginning of the year on 30 grade VIII students. The results showed that 65% of students had difficulty determining sequential pairs (x,y) of function rules, and 70% of students could not draw graphs of simple functions such as f(x)=2x+1. To reduce this difficulty, the teacher planned the order of delivery of the material. Which sequence is most effective for reducing student difficulty? A. PLSV – Function – Cartesian Coordinates – Relations B. PLSV – Cartesian Coordinates – Relations – Functions C. PLSV – Relations – Functions – Cartesian Coordinates

	B. Number Pattern – Cartesian Coordinates – Relations – Functions – PLSV C. Number Pattern – Cartesian Coordinates – Relations – PLSV – Function D. PLSV – Number Patterns – Cartesian Coordinates – Relations – Functions E. PLSV – Cartesian Coordinates – Number Patterns – Relationships – Functions **Note:** The word "diagnostic" needs to be clarified again. The answer option "Number Pattern" does not need to be included.	D. Cartesian Coordinates – Relationships – Functions – PLSV E. Cartesian Coordinates – Relations – PLSV – Functions
18	Mrs. Sari explained that the median definition is the middle value of the sorted data, some students asked: "What are we learning this for, ma'am? Wouldn't it be easier to use average?" As Mrs. Sari, what is the most effective action to show the difference between the median and the average? A. Ask students to calculate the median and average of the math test data, and then compare the results. B. Write down the student's favorite number data (1, 3, 5, 8, 8, 6, 2) and ask "What size do you think is more representative of the student's favorite number?". C. Providing two sets of data, namely data on reading duration per day (30 minutes, 40 minutes, 50 minutes, 60 minutes, 250 minutes) and food prices in the canteen (Rp5,000.00; IDR 7,000.00; IDR 10,000.00; IDR 12,000.00; Rp50,000.00) then students find the median value of each data and ask students to write it down. D. Provide practice questions as much as possible so that students know the difference between mean and median based on the questions they are working on. E. Presenting employee salary data and test score data, then ask "What do you think is the most appropriate measure (mean/median/mode) to represent each data?. **Note:** Create a teacher's knowledge level for each answer choice.	Mrs. Sari explained that the median definition is the middle value of the sorted data, some students asked: "What are we learning this for, ma'am? Wouldn't it be easier to use average?" The most appropriate example of action given by Mrs. Sari to show the difference between median and average is.... A. Mrs. Sari presented some data of 80, 85, 75, 70, 60, 55, 50, 65, 70, and 90, then calculated the median and average values on the board. B. Mrs. Sari presented the data of the test scores: 50, 55, 60, 70, 75, and 85, then discussed the concentration values that represented the data. C. Mrs. Sari presented employee salary data: 5 million; 4 million; 3 million; 100 million; 2 million; 1.5 million; and 2 million and the test value data: 50, 55, 60, 70, 75, and 85, then present the data in a bar chart to see the difference. D. Mrs. Sari presented the test score data in class: 85, 90, 100, 90, 85, 0, 0, 90, 95, 95, then asked the students to calculate the median and average with the formula. E. Mrs. Sari presented employee salary data: 5 million; 4 million; 3 million; 100 million; 2 million; 1.5 million; and 2 million, then discuss the centering value that represents the data.

One of the important indicators in assessing the achievement of learning objectives is the quality of the assessment instruments used, one of which is in the form of questions [37], [38]. Therefore, the process of validating questions by experts is a crucial step to ensure the quality and accuracy of questions in measuring targeted competencies. In this development study, the instrument designed aims to measure Mathematical Knowledge for Teaching Numeracy (MKT-N) in high school mathematics teacher candidates. Given these goals, it is necessary to ensure that each question item developed truly reflects the construct of the MKT-N ability that is to be measured. As part of the development procedure, the initial draft of the question was validated by two mathematics education experts. The validation results showed an average score of 0.98 which was included in the good category, indicating the suitability of the questions with the MKT framework and numeracy competence. This validation also includes aspects of

material substance, language clarity, quality of answer options, and suitability and relevance of the context of the question, which is in line with the principles of quality question writing as described by [39], which includes the accuracy of the material, logical construction, and communicative language.

IV. CONCLUSION

Based on the findings of the research and the results of the analysis, it can be concluded that the MKT-N test instrument developed for prospective mathematics teachers at the secondary school level shows feasibility for use. This conclusion was obtained based on the results of validation by experts who placed the questions in the good category. Referring to these results, the researcher recommends that the development process be continued to the empirical trial stage to evaluate the psychometric quality of the questions more comprehensively, including aspects of validity, reliability, difficulty, and differentiation. After the characteristics of the questions are well measured, this instrument can be used optimally to assess the ability of MKT-N prospective teachers, as well as to be a reference in the development of advanced questions with a more varied and relevant numeracy context to actual issues in society. Furthermore, these questions also have the potential to be used by prospective teachers as a means of practice to strengthen their numeracy mastery in the context of teaching.

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