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Development and Validation of Manipulative materials for kindergarten mathematics

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Abstract. Manipulative materials allow students to explore mathematical concepts tangibly, fostering their mathematical skills. The focus of this study is to develop and validate manipulative materials that align with the kindergarten curriculum. The validation focused on content that was based on 20 experts' evaluations, indicating the relevance and essentiality of the manipulative. The manipulative achieved high levels of content validity, supporting the rating of manipulatives as relevant and essential. Moreover, experts confirmed that the materials showed high content validity with certain revisions of the manipulative material developed.

Keywords: *Kindergarten;Mathematics;Manipulatives;Development;Validation*

Introduction

Mathematics is a fundamental subject in education, shaping the world around us. While many countries prioritize math instruction from kindergarten onwards, challenges remain in ensuring effective learning. One significant obstacle is the lack of engaging materials and resources in the learning process. This can lead to complex information delivery that hinders student understanding and creates a negative impact on their mathematical development. According to Burn; Larbi & Mavis, and Yensi, (2020), using manipulative materials will improve the students through the manipulation of things they will learn from mathematics. It also helps enhance the teaching and learning strategies of teachers. A relevant literature review on the effectiveness of math manipulatives in kindergarten is provided by Hurst and Linsell (2020). This study highlights that using manipulatives significantly enhances students' understanding of mathematical concepts, as evidenced by improved assessment scores and conceptual mastery. The review emphasizes the importance of physical interaction with these materials for developing numeracy skills among young learners. The findings support the notion that manipulatives foster engagement and deeper comprehension in early mathematics education

The study by Kullberg (2020) stated that learning addition, subtraction, and counting numbers in kindergarten is crucial for several reasons. One of the reasons is the evidence of the study conducted at the University of California in which a strong math problem in kindergarten can impact lifelong performance. According to Sezuni, (2022). This study discusses the significance of early number sense development and outlines

learning trajectories that can guide educators in fostering mathematical understanding in young children. The authors emphasize the importance of integrating number sense into early childhood education curricula to enhance overall mathematical proficiency (Clement & Sarana, 2020). The advantages of addition and subtraction in learning field exercises for student MD as evidenced by prior research and the importance of addition and subtraction fact and calculation skills to develop an ability to use mathematics, especially in the methods to solve a problem (Lin,2021) we examine the influence of a fact and computation.

Each exercise within the context of math word problem intervention involves addition and subtraction to arrive at an answer to that word problem. Researchers believe that each practice can be the road to success in solving the math problem. The researchers investigated the development of manipulative materials to determine their importance in teaching, especially in mathematics. The researchers also aimed to determine the methods kindergarten teachers should employ when integrating these materials into their instruction. According to Petersen and McNeil (2021), not only do teachers use manipulatives to help students gain a better understanding of math concepts, but manipulatives aid in keeping students engaged in their learning and the content of the curriculum.

The main goal of this study is to develop and validate the manipulative materials for kindergarten mathematics. Developing manipulative materials can benefit teachers for their lesson, collaboration and engage students in hands-on activity in the field of mathematics. These are beneficial when it comes to presenting things that can help in the proper teaching of mathematics to children. It is expected that this will be useful to help students gain a deeper understanding of how to successfully use the materials and how these become effective.

Theoretical Framework

The study was guided by the constructivist learning theory, which emphasizes that young children's mathematical understanding is closely linked to sensory perception and concrete experiences (Piaget, 1952). Manipulatives serve as effective tools in mathematics education, facilitating the transition from concrete to abstract understanding. Children who engage with physical objects develop clearer mental images and can represent abstract concepts more fully than those with limited concrete experiences (Heddens, 1986). This grounding in manipulative experiences helps bridge the gap between their everyday world and abstract mathematical concepts (Dienes, 1960). Constructivism also posits that individuals develop understanding through personal experiences and connections, reinforcing the importance of content validity in educational materials.

In addition, To develop and validate manipulative materials in kindergarten mathematics is a critical effort aimed at helping young children better understand numbers and how things go mathematically through concrete practices. Anchored on constructivist learning theory, this learning activity considers that children learn best when they are able to engage with concrete materials that relate to their sensory

perceptions. A study on the development of manipulative materials designed specifically to tackle number and number sense can provide related resources that not only capture children's attention but also help them understand abstract concepts in mathematics. Such an approach is in the belief that learning and understanding occurs when any form of new knowledge is related to existing experiences (Piaget, 1952).

Moreover, the study will validate these manipulative materials by assessing them according to their relevance and essentiality. Relevance refers to the suitability of materials to the developmental level of kindergarten students and their alignment with curricular goals, while essentiality affirms that they are indispensable tools in stimulating mathematical understanding. Hence, through rigorous scrutinization of these criteria, the study hopes to establish content validity wherein the manipulative materials support children's learning processes effectively. This validation process is necessary to ensure that materials engage students, yet also play a very important role in the development of the mathematics of their students, thus bridging the gap between concrete experiences and abstract reasoning in mathematics education (Heddens, 1986; Dienes, 1960).

Research Objectives

This study aims to develop and validate manipulative materials for kindergarten mathematics. Specifically, the investigation focuses on these objectives:

1. Develop manipulative materials for number and number sense.
2. Validate the manipulative materials according to:

    2.1 Relevance

    2.2 Essentiality

Methodology

Research Locale

This study is conducted at Saint Nicholas of Bari School located at P22J+HH5 Franco St. Novaliches Quezon City SY. 2023-2024

Figure 1.

Map showing the location of St. Nicholas of Bari School.

Participants of the Study

The participants of the study were 20 kindergarten teachers of St. Nicholas of Bari school who were the chosen experts. These teachers were particularly chosen for their active involvement in early childhood education and their knowledge of how to use instructional materials. The investigation utilized purposive sampling to select the participants of the study based on their experience in teaching mathematics to kindergarten pupils. Through purposive sampling, this research aims to get specific, relevant data from expert teachers who can provide significant insights into this exploration.

Research Design and Instrument

This investigation focuses on developmental research design. Developmental Research is a systematic study of developing, designing, and evaluating educational programs and materials, especially to improve instructional effectiveness. It identifies the ways through which learners interact with new materials and how these materials can improve learning outcomes.(Richey, R. C.,& Klein, J.D. 2005).

In the context of "Development and Validation of Manipulative Materials for Kindergarten Mathematics," developmental research is used to create effective educational tools tailored to kindergarten students. This approach ensures that the materials are not only theoretically sound but also practically validated. The study covers testing the content validity of the materials.

The manipulatives used Addition and subtraction through fingers, pizza matching numbers, popsicle counting and sorting, color sorting, and counting. These manipulatives are created by researchers to test and improve upon tools that are visually representative of mathematical concepts, thus making it fun and easy for kids to learn. Additionally, manipulatives are measured by their relevance and essentiality. The items for relevance of the manipulative materials are based on the MELCS (Most

Essential Learning Competencies). Furthermore, items of essentiality of the manipulative materials are according to Hurst & Linsell, (2020); Dinsmoor, (2022).

DATA ANALYSIS

The researchers used these statistical measures to ensure that the developed manipulative materials were validated using CVI, KAPPA, and CVR for their relevance, and essentiality respectively. While CVI and KAPPA focused on the alignment of the materials to the curriculum and the learning aims, CVR checked for the appropriateness of the materials for achieving the desired learning outcomes as per the experts. Kappa statistics was used to address the issue of chance agreement in expert judgments. These measures of content validity imply that such materials should be efficacious in imparting kindergarten math skills.

Results

The study's findings, focusing on the kindergarten mathematics manipulatives, were rated as relevant and essential, and this was supported by the individual items attaining high levels of content validity (I-CVI) 0.9 to 1.0 (CVR) 1.0 Kappa: 1.0555-1.1234). On the contrary, the overall scale-level validity (S-CVI/Ave: 0.625) was below acceptable levels, because according to Davis (1992) stated that the minimum S-CVI should be 0.8 for reflecting accepted content validity. indicating that the manipulative materials need to be reworked. The experts validated that the materials were engaging and enhanced understanding, yet further content validity alignment was needed (See Table 1 to 3).

Table 1. 13-item Rating Scale CVI by 20 experts:

	CVI									
Item	**Expert 1**	**Expert 2**	**Expert 3**	**Expert 4**	**Expert 5**	**Expert 6**	**Expert 7**	**Expert 8**	**Expert 9**	**Expert 10**
1	4	4	4	4	4	3	2	4	4	4
2	4	4	4	4	3	4	2	4	4	4
3	4	4	4	4	4	4	3	4	4	4
4	4	4	4	4	4	4	2	4	4	4
5	4	4	4	4	4	4	3	4	4	4
6	4	3	4	4	4	4	2	4	4	4
7	4	3	4	4	3	3	3	4	4	4
8	4	4	4	4	4	4	3	4	4	4
9	4	4	4	4	3	4	2	4	4	4
10	4	4	4	4	4	3	1	4	4	4
11	4	3	4	4	3	3	2	3	4	4
12	4	3	4	4	4	3	2	4	3	4
13	3	3	4	4	4	4	2	3	3	4

	CVI									
Item	**Expert 11**	**Expert 12**	**Expert 13**	**Expert 14**	**Expert 15**	**Expert 16**	**Expert 17**	**Expert 18**	**Expert 19**	**Expert 20**
1	4	3	4	4	4	4	4	4	4	4
2	4	4	4	4	4	4	4	4	4	4
3	4	4	4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4	4	4	4
5	4	4	4	4	4	4	4	4	4	4
6	4	4	4	4	4	4	4	4	4	4
7	4	4	4	4	4	4	4	4	4	4
8	4	3	4	4	4	4	4	4	4	4
9	4	3	4	4	4	4	4	4	4	4
10	3	3	4	4	4	4	4	4	4	4
11	4	4	4	4	4	4	4	4	4	4
12	4	4	4	4	4	4	4	4	4	4
13	4	4	4	4	4	4	4	4	4	4

Note. CVI=content validity index

CVI

Item	No. in agreement	I-CVI
1	18	0.9
2	19	0.95
3	20	1.00
4	19	0.95
5	20	1.00
6	19	0.95
7	20	1.00
8	20	1.00
9	19	0.95
10	19	0.95
11	19	0.95
12	19	0.95
13	19	0.95

Note. S-CVI (Average) = 0.625 . I-CVI, Pc,; S-CVI

Table 2**.** 7-item Rating Scale of CVR by 20 experts:

	CVR									
Item no.	Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Expert 9	Expert 10
14	3	3	3	3	3	3	3	3	3	3
15	3	3	3	3	3	3	3	3	3	3
16	3	3	3	3	3	3	3	3	3	3
17	3	3	3	3	3	3	3	3	3	3
18	3	3	3	3	3	3	3	3	3	3
19	3	3	3	3	3	3	3	3	3	3
20	3	3	3	3	3	3	3	3	3	3

	CVR									
Item no,	Expert 11	Expert 12	Expert 13	Expert 14	Expert 15	Expert 16	Expert 17	Expert 18	Expert 19	Expert 20
14	3	3	3	3	3	3	3	3	3	3
15	3	3	3	3	3	3	3	3	3	3
16	3	3	3	3	3	3	3	3	3	3
17	3	3	3	3	3	3	3	3	3	3
18	3	3	3	3	3	3	3	3	3	3
19	3	3	3	3	3	3	3	3	3	3
20	3	3	3	3	3	3	3	3	3	3

CVR		
Item	**No. in agreement**	**CVR**
1	20	1.00
2	20	1.00
3	20	1.00
4	20	1.00
5	20	1.00
6	20	1.00
7	20	1.00

Note. CVR = content validity ratio

Table 3.13- Item Rating scale of the experts for each item

Item	No. in agreement	I-CVI	Pc	Kappa statistic	Interpretation
1	18	0.9	1.81	1.1234	Excellent
2	19	0.95	1.90	1.0555	Excellent
3	20	1.00	9.53	1.0000	Excellent
4	19	0.95	1.90	1.0555	Excellent
5	20	1.00	9.53	1.0000	Excellent
6	19	0.95	1.90	1.0555	Excellent
7	20	1.00	9.53	1.0000	Excellent
8	20	1.00	9.53	1.0000	Excellent
9	19	0.95	1.90	1.0555	Excellent
10	19	0.95	1.90	1.0555	Excellent
11	19	0.95	1.90	1.0555	Excellent
12	19	0.95	1.90	1.0555	Excellent
13	19	0.95	1.90	1.0555	Excellent

Kappa statistic

Note. Pc=probability of chance agreement

Moreover, the median and interquartile range of the experts' ratings on the relevance and essentiality were also utilized to illustrate the overall validity of the developed materials. Table 4 presents the Likert scale intervals and the corresponding relevance and essentiality ratings of the manipulatives developed.

Table 4. Likert interval scale and its corresponding ratings of relevance and essentiality description

Scale	Interval	Ratings of Relevance	Ratings of Essentiality
4	3.26 – 4.00	Highly Relevant	Highly Essential
3	2.51 – 3.40	Quite Relevant	Quite Essential
2	1.78 – 2.50	Somehow Relevant	Somehow Essential
1	1.00 – 1.75	Not Relevant	Not Essential

Data revealed in Table 5 shows the overall median and interquartile range for the relevance and essentiality ratings of the developed manipulatives material according to 20 experts. The median relevance rating (*M*=3.69) with an interquartile range (IQR) of .173. This indicates that the ratings on the content of the materials are highly clustered around the median, reflecting a consensus that the variable is highly relevant and essential. Conversely, the essentiality median rating is 3.00 with an

interquartile range of 0.000, showing complete agreement among experts, although at a moderate level of essentiality. Thus, the data suggests that while both variables are considered important, relevance is rated slightly higher and with more varied responses compared to essentiality, which shows unanimous but moderate agreement.

Table 5. The overall median and interquartile range of the ratings of relevance and essentiality (n=20)

Variables	Median	Interquartile range	Interpretation Relevance	Interpretation Essentiality
Relevance	3.69	.173	Highly Relevant	Highly Essential
Essentiality	3.00	.000	Quite Relevant	Quite Essential

Conclusion

This study focused on developing and validating manipulative materials, specifically the content validation of the developed material. The design, content selection, and curricular standard alignment were all carefully considered during the development process. Aligning the content with the intended mathematical ideas and kindergarten students' learning objectives ensures content validity. The validation focused on content based on 20 experts' evaluations, indicating the relevance and essentiality of the manipulative.

The manipulative achieved high levels of content validity, supporting the rating of manipulatives as relevant and essential. Moreover, experts confirmed that the materials showed high content validity with certain revisions of the manipulative material developed.

Recommendation

The researchers recommend the use of manipulative materials in the actual classroom setting for teaching mathematics to kindergarten students by applying these tools to enhance their learning experience. They also recommend adaptable materials suited to different learning environments and the diverse needs of students. Furthermore, they suggest incorporating real-time feedback systems to motivate learners and facilitate their understanding of mathematical concepts.

Additionally, the researchers recommend conducting seminars and training sessions for teachers to enhance their understanding of manipulative materials and their

effective use in teaching. These seminars would help educators explore creative approaches for using manipulatives to create engaging and meaningful learning experiences. By equipping teachers with the necessary knowledge and skills, these initiatives aim to enhance the potential of manipulatives in nurturing young learners' mathematical skills and overall cognitive development.

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Conflict of Interest: The authors declare no conflict of interest

Ethical Statement: Researchers followed the rules of the 1975 Helsinki Declaration when publishing research involving human participants. All subjects gave their informed consent for inclusion in the study before participating. The research protocol was approved by the QCU Research Ethics Board (Project identification code), and the study followed the Declaration of Helsinki.

Appendix

Research Instrument

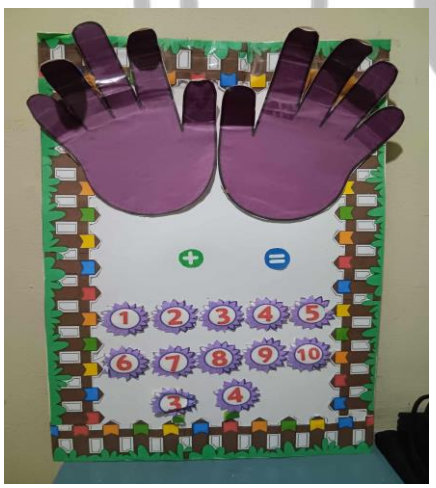

Table 6. Items in the instrument

Relevance (13)
1. Count objects with one-to-one correspondence up to quantities of 10.
2. Compare two groups of objects to decide which is more or less or if they are equal. Identify sets with one more or one less element.
3. Recognize and identify numerals 0 to 10.
4. Match numerals to a set of concrete objects from 0 to 10.
5. .Identify the number that comes before, after, or in between Identify the number that comes before, after, or in between.
6. Arrange three numbers from least to greatest, greatest to least.
7. Identify the 1st, 2nd, 3rd, up to 10th object in a given set.
8. Recognize the words "put together"and "add to, and "in all" that indicate the act of adding whole numbers.
9. Recognize the words "take away" and "are left" that indicate the act of subtracting whole numbers.
10. Combine elements of two sets using concrete objects to represent the concept of addition.
11. Take away quantity from a given set using concrete objects to represent the concept of subtraction
12. Add quantities up to 10 using concrete objects.
13. Subtract quantities up to 10 using concrete objects.
Essentiality (7)
14. Manipulatives enhancing teamwork.
15. Manipulatives increasing participation.
16. Manipulatives aiding in individualized teaching.
17. Manipulatives giving quick assessment.
18. Manipulatives enhancing retention.
19. Manipulatives improving creativity.
20. Manipulatives provide means to learn effectively.