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Review

Conceptual knowledge in area measurement for primary school students: A systematic review

Hafiz Idrus, Suzieleez Syrene Abdul Rahim* and Hutkemri Zulnaidi

Department of Mathematics and Sciences Education, Faculty of Education, Universiti Malaya, 50603 Kuala Lumpur, Malaysia; idrus.hafiz89@gmail.com (H.I.); suzieleez@um.edu.my (S.S.A.R.); hutkemri@um.edu.my (H.Z.)

* **Correspondence:** Email: suzieleez@um.edu.my

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Abstract: Discussions about teaching area measurement in primary school have been ongoing over some decades. However, investigations that thoroughly examine the current research on conceptual understanding in area measuring in elementary schools are still lacking. The objective of this paper is to review whether conceptual knowledge in area measurement may support students to obtain better results in primary schools. This study is to gain insight into how conceptual knowledge in area measurement has been portrayed for primary school students, and reveal possible omissions and gaps in the synthesized literature on the subject. To gather information, two databases were used: Scopus and Web of Science. Primary searches pulled up many studies on the subject of investigation. After analyzing abstracts and eliminating duplicates, our systematic review indicates that there seems a direct link between conceptual understanding and area measurement in primary school mathematics. Hence, teaching children the principle of area measurement rather than a procedure for solving problems seems to be the most effective way of improving problem-solving skills and conceptual understanding for primary students.

Keywords: conceptual knowledge, geometry, area measurement, mathematics, primary school, systematics literature review

1. Introduction

According to Hiebert [10] knowledge with extensive linkages can be defined as conceptual knowledge whereas conception is a generalized or abstract idea based on specific evidence [10, 23, 30]. Mathematical knowledge is generally split into two components in research: procedural knowledge and conceptual knowledge [10]. Procedural knowledge is generally described as knowledge of sequences of procedures or activities that may be utilized to solve issues, which has been associated with research in a number of mathematical fields [23]. According to this theoretical definition, procedural knowledge is examined in a somewhat uniform way: participants solve a set of questions, and a score is generated depending on how many right answers they got or the precise processes they took to get those answers.

However, rather than focusing on procedural knowledge, a growing literature on conceptual knowledge has recently eclipsed the number of procedural studies [6]. There has been a movement toward studying people's grasp of mathematical concepts in general, rather than just how they solve problems. The new ideas have generated conceptual shifts towards reorganizing pupils' previous knowledge [31]. This transition in research from methods to conceptual understanding reflects a similar trend in mathematical education.

Individuals who understand the conceptual underpinnings of a process are more likely to effectively generalize into innovative situations and to assist people in determining which technique is appropriate in a specific circumstance [18, 27]. It has also been claimed that conceptual understanding may have broader implications. For example, the Common Core State Standards Initiative [5] stated that educating conceptual knowledge in addition to processes is a means to develop broader and longer-lasting mathematical comprehension. As a result, there is a widespread perception that conceptual knowledge is crucial to arithmetic learning. With young children, the approach to geometry begins with the pupils' informal knowledge of circumstances, which is then followed by a progressive mathematical reconstruction of these experiences [16]. Studies in mathematical thinking, learning, and instruction from a variety of theoretical viewpoints could benefit from a better understanding of conceptual knowledge.

In Malaysia, geometry has been taught in primary schools. The Ministry of Education is constantly reviewing their curricula to ensure that the curriculum is being implemented in schools and that students are being equipped with the knowledge, skills, and values they need to face current and future challenges. Standard Curriculum for Primary School (KSSR) has been reviewed and structured over time. According to the 2019 report of the Trends in International Mathematics and Sciences Study (TIMSS), Malaysian students' average score in Geometry and Measurement is moderate (achievement score of 466) compared to the neighbor Singapore (achievement score is 619). This means that Malaysian students only have a basic understanding of Geometry and Measurement, and students may lack of an ability to calculate areas, perimeters, and volumes of geometric objects. Although Geometry and Measurement is an excellent topic for students to learn through all types of numbers and numerical operations at all levels, it is better to learn these in real-world measurement contexts naturally. As a result, it is critical for students to understand that geometry and measurement learnt in primary schools will become the foundation for continuing study in secondary schools.

Geometry is an area of mathematics that is used in nearly every field, including engineering, science, business, computer science, and information systems. Geometry measuring demands the use of both concepts and skills [30]. According to Battista [1], students use the processes of action, reflection, and abstraction to build on and update their preexisting mental structures in order to generate new knowledge and make sense of unusual events. Geometry measurement is still widely utilized in everyday mathematics. This study aims to explore how conceptual knowledge in geometry may be utilized to advance learning mathematics in general as mathematics has a reputation for being a topic that involves a lot of memorizations of information in order to solve problems [26]. To achieve this goal, a systematic literature review concentrating on area measurement in primary schools is conducted.

2. Problem statement

Instructors often found that new students were struggling with area and measurement. This might be due to misunderstandings, mixing up the terms of area and perimeter, or a complete lack of understanding of the idea. Learners may also find it challenging to grasp how the concepts of area and perimeter are used in everyday life [19]. As a result, these concepts must be contextualized in terms of the learners' cultures, customs, and life experiences [11]. Furthermore, the issue may be originated from a simple misunderstanding of terms or from deeper misunderstandings that cause learners to believe that perimeter and area are inextricably related, and that increasing one leads to increasing the other [6]. One huge issue for researchers is that there seems no clear consensus in the literature on what conceptual knowledge is and how to effectively assess it. For scholars interested in mathematical thinking, learning, and instruction, a better grasp of conceptual knowledge would be useful.

3. Objective and method

The purpose of this research is to determine primary school students' conceptual knowledge in area measurement. The following research questions will be addressed in this study:

i. What is the conceptual knowledge in area measurement for a primary school mathematics class?
ii. Why is the area measurement conceptual knowledge that are important in the classroom?

The approach of systematic literature review (SLR) was utilized to examine publications relating to conceptual understanding in geometry in elementary school, particularly in area measurement. Identification, screening, eligibility, and inclusion are the four phases of the SLR strategy [31]. Three strings were used to search for suitable articles during the identification phase. These are 'area measurement', 'area measurement AND conceptual knowledge', and 'area measurement AND primary school'. The term AND is used in the search string in order to not only include a broad range of results but also narrow the search down to a study of conceptual knowledge in particular [8]. A total of 117 documents were successfully collected by the search from Jstor NCTM, Science Direct, ERIC, Elsevier BV, Scopus, SCImago Journal Rank, Web of Science and Springer.

During screening, the 117 papers were reviewed further to limit down the issue to conceptual knowledge, resulting in the removal of 48 studies. The procedure was repeated with the remaining 69 papers by screening the titles and abstracts. This process discovered 24 publications that had the same conceptual understanding in the area measurement subject. Because the main alternative of this SLR process was to include the most relevant publications that contained conceptual knowledge and area measurement independent of subjects or areas, the remaining papers were subjected to a comprehensive review. As a consequence, 18 articles representing conceptual understanding AND area measurement were finally selected. The whole process is outlined in Figure 1.

In the next processes, these papers were thoroughly reviewed by noting certain types of proof on students' performance accomplishments. The conceptual knowledge, area measurement, and framework representation were discovered to be somehow related in these publications. The rest of this article outlines the conceptual knowledge in area measurement for primary schools which was reported in each research.

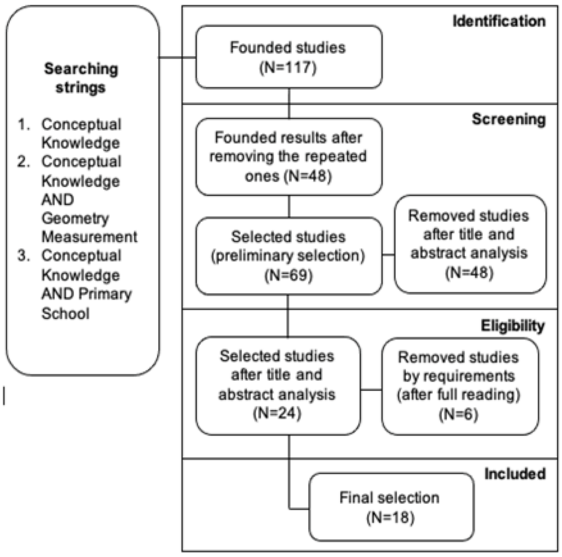

Figure 1. Publications included and excluded from the systematic review

4. Findings

Each of the 18 selected articles was carefully reviewed by the research team with mutual validations from individual team members to ensure consistency with an agreement to the classifications in the analysis. The classified results with respect to conceptual knowledge are tabulated in Table 1 and those with respect to area measurement are tabulated in Table 2.

Table 1. Analysis of conceptual knowledge by paper

Definition	Discussion	Example
Grasp for connection	Within a domain, relationships	"…knowledge that is rich in relationships. It can be thought of as a connected web of knowledge, a network in which the linking relationships are as prominent as the discrete pieces of information." [10]
Rich in relationship	Underlying connections may be few and superficial, or they may be many and deep.	"…the quality of one's knowledge of concepts-particularly the richness of the connections inherent in such knowledge" [27]
Static knowledge	Added data that problem solvers add to the problem and utilize to solve it	"…knowledge about facts, concepts, and principles that apply within a certain domain" "…quality characteristic, being the opposite of compiled knowledge" [15]
Knowing what	semantic networks, hierarchies, and mental models are among the constructions used to describe it.	"…consists of the core concepts for a domain and their interrelations" [2]
Knowledge of symbol	the meanings of symbols	"…awareness of what mathematical symbols mean, and the ability to represent relations among numbers in multiple ways."[22]
Knowledge as	covers both general and procedural concepts.	"…an abstract or generic idea generalized

abstract or generic idea	Does not have to be verbalized and might be implicit or explicit.	from particular instances" [23]
Underlying structures	crucial in the development of procedural knowledge, or the how-to of problem solving, since it helps youngsters to find new techniques and modify existing ones when addressing problems	"…understanding of the underlying structures of mathematics" [25]
Explicit or Implicit Understanding	Higher procedural expertise is associated with greater conceptual understanding. Procedural ability comes before conceptual comprehension. Increased procedural expertise may be achieved through both conceptual and procedure training. Increasing conceptual understanding led to the formation of procedures.	"…explicit or implicit understanding of the principles that govern a domain and of the interrelations between pieces of knowledge in a domain" [24]
concepts that define an area and are generalized from specific cases	A variety of phases are used to build concepts; enactive, iconic & symbolic	"…enable us to classify phenomena as belonging, or not belonging, together in certain categories" [13]

Table 2. Analysis of area measurement concept by paper

Concept	Discussion	Examples
The area of a rectangle with sides l_1 and l_2 units is given by the formula A = $l_1 l_2$ square units	Measured in square units, m^2, cm^2 or mm^2	"…The area of a plane figure is the quantity of the plane surface which is enclosed by the perimeter" [21]
A tiling of the plane with congruent regions that become units of measure. Acquisition of shapes, measure, computation of measure. Conceptualizing the row-by-column structure of a rectangular array. Arrangement of columns and rows and meaningfully enumerate arrays of a square by using multiplication	Knowledge is a more complex subject-matter domain that includes the previous idea of area as well as measurement skills.	"…the amount of a 2-D region within a boundary, while area measurement concerns measuring the quantity of a surface enclosed within a 2-D region" [12]
A suitable 2D region is chosen as a unit Congruent regions have equal areas Regions do not overlap, the area of the union of two regions is the sum of their areas • Partitioning, • Unit Iteration, • Conservation, • Structuring an array	To generate a two-dimensional measure, measure the lengths of two sides and multiply these one-dimensional units. An array of units is created by iterating a unit along a rectangular area. Requires multiplicative thinking regarding the product of two lengths.	"…two-dimensional surface that is contained within a boundary and that can be quantified in some manner" [28]
To create a conceptual knowledge of area and perimeter in a concrete way.	Not adequately covered in the lower grades, when learners merely learn to define area as the product of length and breadth (A = l × b), which is completely divorced from the idea of covering surface. Learners need objects or resources like	"…the amount of surface of a region" [17] Learners need objects or resources like bricks and cuttings which they can fit, fold, match and count.

	bricks and cuttings which they can fit, fold, match and count.	
Conserving area as quantity • Understanding area units • Structuring rectangular space into composite units • Understanding area formula • Distinguish area and perimeter	Moving away from physical instruments and toward numerical computing. • In the measuring of teaching and learning, there is a transition. • This course serves as a foundation for more advanced mathematics. • The numerical magnitude of area measurements changes according to the unit's size.	"…the quantity of two-dimensional (2D) space enclosed in shapes with closed boundaries, whether they lie on a plane or non-planar surface. "[14] partitioned into equal parts; area measures are the number of area units that fill the space
• Units of measurement • A measurement system • Suitable formulas	If they do not understand the concept of area, measuring the area of an item might be challenging.	"…Area measurement is based on partitioning a region into equally sized units which completely cover it without gaps or overlaps" [32]
• Transitivity • The relation between number and measurement • Unit iteration • Operate in area measurement similar to length measurement	• Understanding of the attribute area • Equal partitioning • Spatial structuring Conceptual development demand builds to thinking square unit in a row times the number of rows.	"…Understanding of area measurement involves learning and coordinating many ideas." [7]
Poor performance • Don't completely get the relationship between multiplication and addition • The rectangular array's structure is not readily clear to children.	• Inadequate understanding of area and area measurement • Poor stage refers to a proclivity for learning the area formula by role. • Difficulty in generalizing the procedures they have learned	"…involves the coordination of two dimensions." [20] Teachers do not give students enough time to learn about the multiplicative structure of rectangular arrays.
Start with informal knowledge to Ends with formal knowledge within cognitive plateaus (instruction)	What pupils can and cannot accomplish, their conceptualizations and reasoning, cognitive barriers that hinder learning development, and mental processes required for both operating at a level and moving to higher ones	"…To construct new knowledge and make sense of novel situations, students build on and revise their current mental structures through the processes of action, reflection, and abstraction." [1]

5. Discussion

5.1. Conceptual knowledge in area measurement in primary schools

In general, these sources did not adequately express the conceptual understanding needed to support students' efforts to overcome identified learning difficulties in area measurement. According to Hurrell [13], there were a variety of phases used to build concepts which might be (1) active, (2) iconic, and (3) symbolic. It started with the 'active' stage, in which tangible experiences were used to learn. Pictorial and other visual representations were employed at the 'iconic' stage. The final level was the 'symbolic' stage when abstract notation and symbols were deemed appropriate for conveying meaning to the learner. This link could be made between two previously taught mathematical notions or concepts, or between a previously learned concept and a concept that had just been learnt. Rittle-Johnson & Alibali [24] stated that if teachers increased their conceptual understanding, it would lead to the formation of procedures. According to Stephen & Clements [28], area was the quantity of two-dimensional surface that was contained inside the boundary and could be quantified. In [14], an area was explained as the quantity of two-dimensional (2D) space enclosed in forms with secure borders, whether on a plane or non-planar surface. Researchers went on to state that when assigning a number to conceptual area measurement, at least four conclusions could be drawn: (1) partitioning, (2) unit iteration, (3) conservation, and (4) structuring an array. Students must understand the concept of length, how iterations of rows of squares (which can be represented as length or width) could be used to determine areas, and how and why the formulas for areas of various shapes could be applied to solving area problems in order to be successful with area problems and understand the concept of area [11].

Partitioning is the mental process of cutting two-dimensional space with a two-dimensional unit, similar to how area measuring is done [28]. Nevertheless, these philosophical ideas were rarely acknowledged when conservation was partitioned [14]. Teachers often believed that a region was divided into two-dimensional units by the product of two lengths. However, according to the literature, constructing a two-dimensional array from linear units was not easy. Children with considerable experience in measuring areas and a strong memory of the formula may not always have a precise understanding of area [12]. Students' first encounters with area could include tiling a region using a two-dimensional unit of choice and discussing concerns such as leftover spaces, overlapping units, and accuracy. The tiling method used actual tiles to entirely cover a rectangular region [4]. Students could see how certain places might be covered by other 2D sizes in order to completely cover the space due to the limit of the pre-structured materials. They could align figural units by representing them as unanchored, roughly rectangular forms (applied notion of collinearity), although this was generally done intuitively and in one dimension. This would lead to misconceptions or partial conceptions as students were impossible to organize, coordinate, and structure two-dimensional spaces. Their problems remained even after substantial covering and tiling [20].

Another key concept that students built as they studied regions with area units was unit iteration [28]. There should be no gaps or unit overlaps. Students also tended to fill up the region with units, but not to expand units beyond the larger region's limits. This was also one of the strands having more connections both inside and outside of itself. For example, knowing the notion of area laid the groundwork for comprehending the concept of volume and the underlying principle behind both the ruler and the number line [30]. Furthermore, when given the option, students picked units that visually resembled the location they were studying. Unit iteration demanded the capacity to consider the length of a tiny unit, such as a block, as part of the length of the bigger item being measured, and to position the smaller block along the larger object's length repeatedly by counting the iterations of tiling the length without gaps or overlaps [7]. Partitioning implies tiling, or space filling, but this is not well understood by young children who must also understand the necessity for equitable partitioning and hence the usage of similar units. The lack of development of unit iteration may be seen in students' choice of a measurement instrument based on equal length of tool-to-object and their desire to have enough tools (rulers, tape measures, or yard sticks) to increase the length of the item to be measured [3]. As a result, tasks needing the capacity to iterate units should not be included in first-grade mathematics curricula or assessments because this does not appear to be a suitable goal for first grade.

In terms of area measurement, there are two aspects to conservation, the partitioning conservation and the motion conservation [14]. The area of a region remains unchanged when it is partitioned into subset areas, which is called conservation under partitioning. In other words, regardless of the area units used, the area remains the same. In the meantime, under the motion conservation, the area remains constant regardless of the region's position or orientation. According to Cross & Woods [7], most of these concepts, such as transitivity, the relationship between number and measurement, and unit iteration, worked in a similar way in area measurement as they involve length measurement. Understanding the area attribute entails assigning a numerical value to the number of bounded two-dimensional surfaces. Equal partitioning is the mental process of dividing a two-dimensional space into equal-sized sections, with equal partitioning requiring equal-sized parts (usually congruent). Students must then create an array in order to comprehend area as a real two-dimensional geometric object. According to Castle & Needham [3], transitivity emerged before unit iteration. More pupils in that research exhibited transitivity than unit iteration at the start and conclusion of the school year. There were no instances of a pupil demonstrating unit iteration without transitivity.

The concept of spatial structuring in this context includes identifying the goal of partitioning a territory into parts and organizing the area into a row-and-column structure, with the final result being a fully partitioned and measured region. Then, the linear dimensions of the rectangle area determine the structure [4]. The use of a unit square to create a row of units is an example of spatial structuring, which takes previously abstracted things as content and combines them to form new structures. According to Battista et al., [1], for pupils, structuring an array was a very difficult task, especially in the early grades. He claimed that pupils must acquire such structure in order to comprehend area, and that children should learn things at different levels as seen in the Table 3.

Table 3. Levels of comprehend area

Level	Descriptions
1	There is no usage of a composite unit consisting of a row or column of squares (a "line" of squares thought of as a group). At this level, students have trouble visualizing the position of squares in an array and counting square tiles that cover the inside of a rectangle.
2	Partially structured rows or columns. Some pupils, for example, only construct two rows.
3a	A set of rows-or column-composites is used to structure an array. At this level, students view the rectangle as being covered by copies of composite units (rows or columns), but they are unable to correlate them with the other dimension.
3b	Iteration in a visual row or column. If they can see the rows, these pupils can iterate them (for example, count by fours).
3c	Iteration in the inside of a row or column. These kids may use the number of squares in a column to iterate a row. The traditional "formula" approach of estimating area will only have a strong conceptual basis for most pupils at this level.

Adapted from Battista et al., [1]

5.2. The importance of conceptual knowledge in area measurement for primary school

Students face several challenges as they learn to measure area. To figure rectangular areas, they need to first measure the lengths of two sides, then multiply these one-dimensional units to get a two-dimensional measure. Tan Şişman & Aksu [30] found that students exhibited inadequate understanding of 'what to measure' and 'how to measure', and hence were challenged to tackle word problems requiring measurement. Students had trouble in generalizing methods they had learnt but had not comprehend the conceptual knowledge underpinning for the formula [20]. There were two issues with this for starters. Firstly, many pupils may not completely comprehend the relationship between multiplication and addition. Secondly, there was evidence that the rectangular array's structure was not intuitive to toddlers [14, 28]. Hiebert [9] claimed that students' mathematical competence was largely based on their understanding of both mathematical concepts and procedures, and that by understanding what or why and how to do, students could make sense of mathematics and easily adapt their conceptual and procedural knowledge in problem-solving situations. In terms of measuring domains, student's performance dropped from one-dimensional (length) to two-dimensional (area) to three-dimensional (volume).

According to Rittle-Johnson & Alibali [23], children with good conceptual understanding could grasp the entire meaning of the equal sign and how to utilize it in a variety of situations. When it came to helping students comprehend the structure of equations, conceptual teaching was somewhat more successful than procedural education. Conceptual teaching resulted in the highest increases in conceptual understanding and the most transferrable problem-solving abilities in this study. Children who received conceptual training developed numerous processes on occasion, and were able to adapt their procedures to new situations. These findings indicate that, in some situations, children may gain the most from conceptual teaching that enables them to create proper processes by themselves.

6. Conclusion

In conclusion, the current research focuses on the linkages between conceptual understanding and area measurement. It shows that conceptual instruction could result in developing proper and flexible processes to address issues in teaching inefficiency and learning consistency in school mathematics, and to improve conceptual understanding in the context of area measuring for primary school students. Utilizing the direct relationship between conceptual understanding and area measurement would foster growth of mathematical ability interactively and iteratively for young students. Hence, teaching children the principle of area measurement rather than only a procedure for solving problems seems to be the most effective way of improving problem-solving skills and conceptual understanding for primary school students.

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Author's biography

Hafiz Idrus is a PhD candidate in Mathematics Education at the Faculty of Education, Universiti Malaya. He is a primary school teacher and his research interest is in mathematics education in primary school.

Associate Professor Dr. Hutkemri Zulnaidi is an Associate Professor in the Department of Mathematics and Science Education at the Faculty of Education, Universiti Malaya. He specializes in mathematics education, technology in education, problem solving, assessment and measurement, statistics, and quantitative research.

Dr. Suzieleez Syrene Abdul Rahim is a Senior Lecturer in the Department of Mathematics and Science Education at the Faculty of Education, Universiti Malaya. Her area of specialization is mathematics education. Her research interests also include assessment, pedagogy, teachers' beliefs, qualitative research, and teacher development.