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Systematic Review: Student Skills and Psychology in Multiplication Operations

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Abstract

Purpose: Students' skills in multiplication operations are rudimentary skills that students need to master. The teacher must demonstrate mastery as many students misconstrue the concept of multiplication.

Theoretical framework: Analytical studies on multiplication strategies are still lacking, with most studies concentrating more on interventions in the teaching and learning of multiplication topics. Besides, the systematic literature review on multiplication is still lacking.

Design/methodology/approach: For this research, 20 journal articles were reviewed based on data from ERIC.

Findings: The analysis confirmed that errors in the concept of multiplication and various multiplication methods had been examined in several mathematical topics in all these studies.

Research, Practical & Social implications: The concept of multiplication is one of the critical skills in daily life. This learning process demands proper techniques and methods in determining the direction and future of students. There are several distinct approaches according to student mastery. Therefore, this concept of multiplication is paramount before starting teaching higher-level topics in mathematics.

Originality/value: The concept of multiplication is vital to children in calculations, and it starts from small numbers to large numbers. This concept also involves taxing facts for children to measure. The children find the same basic concept of multiplication repeated several times by teachers confusing, and hence, similar errors occur among children. The process of introducing concepts to children is a critical matter before starting teaching, and this implies that children are inquisitive in understanding concepts in depth.

Keywords: Students' skills, multiplication operations

1. Introduction

The fundamental component in this concept of multiplication relies on the teacher's strategy in planning lessons and aligning the techniques taught with the level of mastery of the students' group (Kaur et al., 2017). There are many techniques and methods employed to understand multiplication by children. Some involve gaming, memorising, mental calculation (*congak*), the clock, and the iPad (Schulz & Schulz, 2018). Nonetheless, every technique and method operated in teaching is merely a tool in comprehending the concept of multiplication to children (Simmons, Willis, & Adams, 2012). New approaches have been introduced to children in the use of multimedia learning. This multimedia learning has made possible using a virtual manipulative environment, and the influence is constructive that student achievement in the concept of multiplication advances dramatically (Paek, Hoffman, & Black, 2016). Additionally, technology has also introduced the compelling multiplication concept in the iPad. Ipad has been the subject of the investigation to explore the effectiveness of mastery of multiplication among students. These investigations established its practicality for students and multiple constraints in tools and infrastructure (Bakker, Heuvel-panhuizen, & Robitzsch, 2015).

Based on the background of students' skills in understanding the concept of multiplication, this study aimed to conduct a systematic literature review to answer some questions, including 1. Lack of analytical studies on multiplication strategies where most studies focus more on interventions in teaching and learning the topic of multiplication and 2. Lack of systematic literature review on the topic of multiplication. Hence, this research attempted to answer all questions and obtain impactful results.

Hence, the researchers constructed a conceptual framework of multiplication based on previous models and studies (Dapaepe, Verschaffel, & Kelchtermans, 2013). The establishment of this conceptual framework or concept of multiplication aspired to facilitate researchers to complete research and further confirm the hypothesis based on the conceptual framework to be matched with research data. Based on the built conceptual framework, the researchers could ensure that the study was on track to fulfil the study's objectives. In addition, this framework could also help the researchers design, set the scope, construct realistic and pertinent research questions for the study, select appropriate methods to collect data and analyse the study.

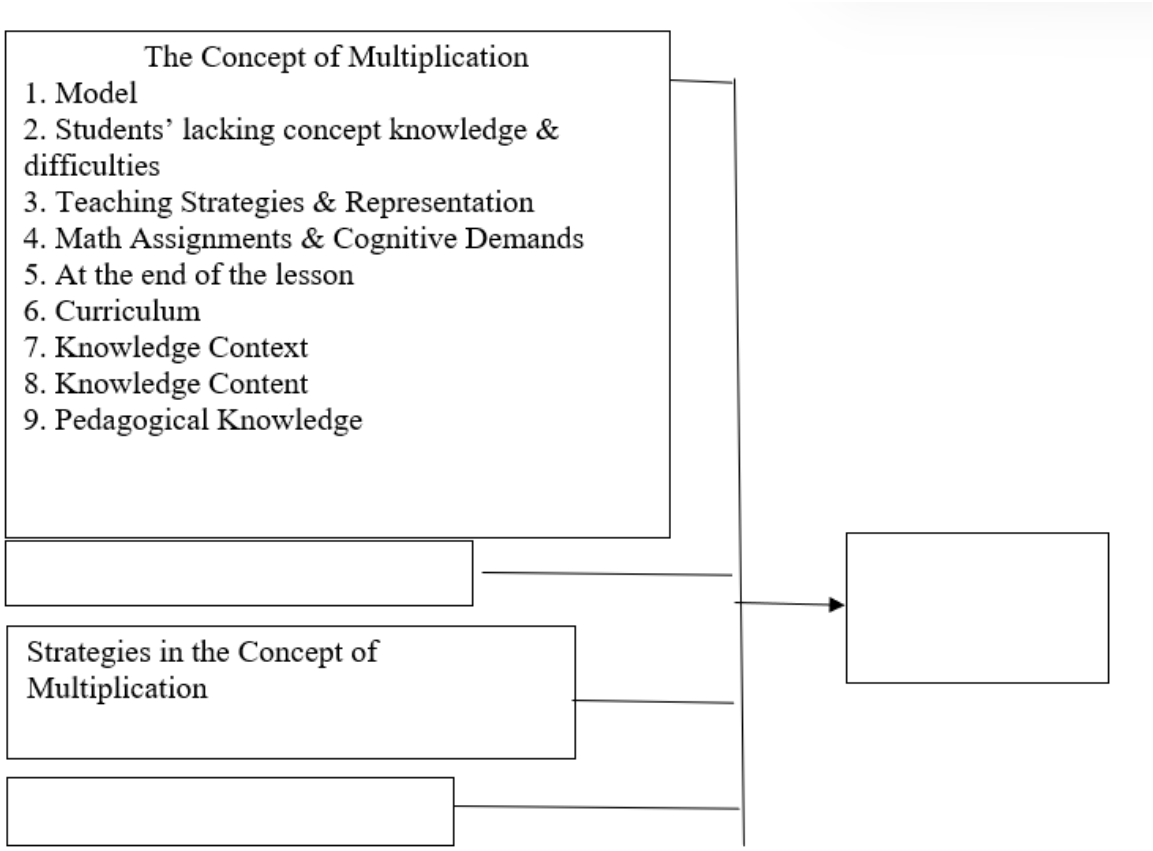

Figure 1: Conceptual framework for the concept of multiplication modified based on (Dapaepe et al., 2013)

Figure 1 shows the conceptual framework in designing the course of a systematic literature review for the concept of multiplication that was modified from the article of Dapaepe et al. (2013). In this study, the researchers outlined four parts to be analysed in each article: the concept of multiplication, the countries conducting the study, the types of subtopics of multiplication according to age and research methods. Each part that was analysed would be linked to each other to recognise the real strategies in the concept of multiplication. The strategies in this concept of multiplication would be a crucial conclusion in a systematic literature review. Therefore, this conceptual framework would be beneficial in designing the course of this systematic literature review.

2. Material and Methodology

A systematic literature review was reconsidered through the consultation of an international education research information system called ERIC (Education Resources Information Center). The term search included all about multiplication skills (including terms about student skills in multiplication) and all mathematical requirements in multiplication that have been stated in the abstract, keywords and title. In this search, the study on multiplication was set to the following criteria 1. This study used the data from the last nine years from 2010 to 2018 2. This study indicated a background of problems from primary school only because the basis of multiplication starts from primary school 3. Journals were sought only from ERIC (Education Resources Information Center) sources, and 4. Articles sought must be in the form of empirical articles only. The database used was only from ERIC sources, and the keywords searched were multiplication and ability, multiplication on children, concepts of multiplication, and children's ability of multiplication. Over the past nine years, there have been 63 empirical articles in the ERIC database. Nevertheless, only 20 articles were chosen because only these 20 articles met the criteria set by the researchers.

Next, these articles were analysed and categorised according to four tables. These tables could highlight the differences in terms of problems, improvements, and interpretation of the concept of multiplication. In Table 1, there are categories on the concept of multiplication, among them are author, multiplication model, sample size (n), students' lacking concept knowledge and difficulties, teaching strategies and representation, mathematical assignments and cognitive demands, at the end of the lesson, curriculum, knowledge context, knowledge content and pedagogical knowledge. Next, Table 2 presents the countries that conducted the study of the concept of multiplication and among those categorised are continents, countries, total sample (n), and the study conducted. Further, Table 3 offers the types of multiplication subtopics studied according to age and among the criteria placed subtopics, 6 to 7 years, 8 to 9 years, and 10 to 12 years. Furthermore, Table 4 tabulates the research method used, and the categories designated by the researchers are study, total sample (N), experiment, questionnaire, interview, discussion and assignment. Each of these tables would be refined to find the actual value in this concept of multiplication. It would deliver authentic and straightforward results for this systematic literature review..

3. Results and Discussion

Discovery of the concept of multiplication

The notion of multiplication began in formal schools since the early establishment of schools. This concept of multiplication is quintessential as a foundation in everyday life (Fang, Angie, Ricci, & Mathematical, 2016). Thus, in apprehending this concept of multiplication, several articles have stressed the mental concept of arithmetic as in the article (Ding et al., 2016), which specified that the difficulty of multiplication could be overcome by memorisation. However, when the researchers analysed several articles published from several countries, developed countries favoured technology such as the iPad in mathematics learning (Kaur et al., 2017). Furthermore, in different situations, the concept of multiplication has become the focus of society as global economic progress, and students' critical thinking has become a preeminence in fostering a scholarly and prosperous society (Lowrie & Jorgensen, 2018).

Nonetheless, the concept of multiplication is highly accentuated in primary school mathematics. Children aged 7 to 12 years need to understand each concept before high school. All players have taken concrete action in educating students to foster a society with elevated confidence in facing a world without borders.

Nevertheless, psychological studies had recognised less confidence among students about the concept of multiplication learned when they were introduced with large starting numbers (Gibbs et al., 2017). Children easily give up when the conception of teaching is not attractive, and subsequently, students do not comprehend the content of the lesson well (Fang et al., 2016).

3.1.2 Components in multiplication

The selection of components in multiplication resulted in several essential selections to categorise the importance of the concept of multiplication in mathematics learning. Table 1 shows eight crucial components to be analysed, namely 1. Students' lacking concepts knowledge and difficulties 2. Teaching strategies and representation 3. Mathematical assignments and cognitive demands 4. Teaching Outcomes 5. Curriculum 6. Knowledge context 7.

Knowledge content 8. Pedagogical knowledge. Furthermore, table 1 also shows the authors using different multiplication concepts.

The criteria for students' lacking concepts and difficulties implies students lack mastery in multiplication concepts. Previous analyses have proved that students lack basic facts about multiplication (Agostino et al., 2010). Basic facts that students cannot measure have risen a student's perspective on using mental strategies in the numeracy phase (Ali & Mutawah, 2016). This strategy is typical for students who struggle in multiplication (Ding et al., 2016). Nevertheless, short-term memory and working memory are necessary to assist each other in helping students remember each procedure and strategy in multiplication (Dubé & Robinson, 2010; Sumarto & Galen, 2014; Ven, Boom, Kroesbergen, & Leseman, 2012). Furthermore, contemporary technology has brought many transformations to students' perceptions in remembering and understanding lessons where the study of multiplication concepts using technology such as iPad and some software have been recognised to support students who lack concepts (Bakker, Heuvel-panhuizen, & Robitzsch, 2015; Kaur et al., 2017; Paek, Hoffman, & Black, 2016; Yang, 2011).

Next, for strategy and representation, several studies have concentrated on exam results before formulating strategies for students who lack the concept of multiplication (Ali & Mutawah, 2016; Dubé & Robinson, 2010; Durham, 2012; Schulz & Schulz, 2018). A common strategy denotes mastery learning where students need to practice daily, and memory is stored in long-term memory (Kaur et al., 2017; Zhao, Valcke, Desoete, & Burny, 2014). In addition, the teacher demonstrates the ways and procedures before students attend their activities individually or in groups. The demonstration is a critical strategy in understanding concepts and procedural in mathematics (Fang et al., 2016; Gibbs et al., 2017; Kaur et al., 2017; Schueler-meyer, 2016). Nevertheless, in today's technology epoch, online games and online assignments are emphasised on students at school and home (Bakker et al., 2015; Kaur et al., 2017; Paek et al., 2016; Yang, 2011).

However, for mathematical assignments and cognitive demands, much emphasis is placed on problem-solving in multiplication operations to investigate how students function in translating a given situation (Agostino et al., 2010; Dubé & Robinson, 2010; Kaur et al., 2017; Schulz & Schulz, 2018; Yang, 2011). Math assignments can reflect their proficiency in the concept of multiplication in a few weeks when each set of assignments is completed successfully. Furthermore, students' cognitive level also grows, and it depends on the understanding of the task assigned and the basic knowledge needs of the students themselves (Agostino et al., 2010). Furthermore, for students' basic mathematical knowledge needs, language plays an integral role in reinforcing the concept of multiplication, where issues in wordy questions symbolise the highest level in reckoning students' critical thinking (Bjork & Bowyer-crane, 2013; Fang et al., 2016).

Next, at the end of the lesson, one can assess the children's ability to master the concept of multiplication, especially in problem-solving (Agostino et al., 2010). However, mental use strategies also have a high impact on numeracy proficiency, especially multiplication (Ali & Mutawah, 2016). Furthermore, students become creative, innovative and responsible in calculating and doing multiplication exercises while enhancing their mastery of concepts (Bakker et al., 2015; Ding et al., 2016; Gibbs et al., 2017). The impact of each study documented positive results on the concept of the multiplication of students. Accordingly, each researcher has well studied the concept of multiplication to obtain authentic findings on the concept of multiplication among students.

Criteria on the curriculum in the concept of multiplication have been identified as relevant to the country's education system under study, where the Bahraini Ministry of education tries to modify the latest calculation methods to mental strategies (Ali & Mutawah, 2016). Furthermore, mixed assessments are used to gauge aspects of student learning outcomes in multiplication skills covering procedural and conceptual knowledge (Bakker et al., 2015). Nevertheless, data verified that before and after teaching, students fail to master the required skills (Durham, 2012). This low level of mastery of concepts needs to be overcome with critical, creative and flexible thinking in finding ways that can help students understand the concept of numbers and multiplication (Fang et al., 2016). Therefore, students will be more responsible in counting and viewing numbers in a flexible way (Gibbs et al., 2017). Nonetheless, the findings from the study of Kaur et al. (2017) established the use of the iPad as an addition to help students understand the concept of numbers, order of operations, expressions and multiplication skills.

Different cognitive processes can be identified in the knowledge context depending on how students use short strategies or ways they understand in solving problem-solving-related questions (Agostino et al., 2010). Therefore,

knowledge context can also reflect the level of students' acquaintance of the concept of multiplication as well as their cognitive abilities, especially in numerical operations where a solid foundation can enhance students' mastery of the concept of multiplication (Ali & Mutawah, 2016; Bjork & Bowyer-crane, 2013; Ding et al. al., 2016; Dubé & Robinson, 2010; Durham, 2012). However, when students' metacognitive skills are developed, they become aware of their learning styles and operate well-founded strategies in the problem-solving group or individual assignments (Fang et al., 2016).

In the meantime, the knowledge content from this concept of multiplication suggests a necessary comprehension process in solving problems containing several steps of computational procedures (Agostino et al., 2010). In addition, student motivation can also grow when computer games are seen as a catalyst to enhance student potential (Bakker et al., 2015). Furthermore, some studies look at understanding relationships and functions that can enable students to manipulate mathematical problems to understand mathematical concepts quickly (Dubé & Robinson, 2010). Thus, discipline is essential for students in developing focused thinking abilities, which require planning and strategies that have been identified as aspects of success for students (Fang et al., 2016).

Next, students need to solve problems even if quite complex for pedagogical knowledge. They need to devise strategies and coordinate mathematical procedures rather than just applying multiplication operations (Agostino et al., 2010). Furthermore, high-impact studies have discussed the essence of using mental calculation strategies to improve students' competence related to numeracy calculations (Ali & Mutawah, 2016). However, each student is unique with their learning style, appeals, family background, cognitive abilities and social and behavioural challenges, which are challenges for teachers (Durham, 2012). In the meantime, when teaching mathematics for problem-solving or computational topics, teachers can support students by expanding mathematical thinking skills related to higher-level mathematics subjects (Fang et al., 2016).

3.2 Reviewing the study of multiplication in mathematics

Empirical studies of multiplication in mathematics in mathematics education that was identified have shown features such as 1. Countries that have implemented the concept of multiplication 2. Types of multiplication subtopics are studied according to age 3. Research methods used along with the number of samples and 4. Important findings in the concept of multiplication.

3.2.1 Country

Table 2 presents the overall differences of the countries applying the concept of multiplication. Among the 20 articles reviewed, several countries that explored the concept of multiplication have been listed, including Canada, Bahrain, Amsterdam, United Kingdom, China, United States, Taiwan, Germany, United Kingdom, Indonesia, and Belgium. Nonetheless, one article did not provide information about the country that analysed the concept of multiplication (Durham, 2012). However, each country examining this multiplication concept has listed varying sample sizes. When compared in these articles, Beijing district located within the People's Republic of China has contributed two different articles in which the article of Ding et al. (2016) has obtained 30 samples and the article Zhao et al. (2014) has cooperated between China and Belgium in his study and has contributed a total of 8160 samples. On the other hand, there was also an empirical article in Fang et al.'s (2016) study, who did not specify the number of samples taken for his analysis. Next, the sample taken in all countries involved between 8 to 8160 people to construct an empirical study on the concept of multiplication.

3.2.2. Types of multiplication subtopics studied by age

Table 3 shows that several subtopics were studied. Among the subtopics were multiplication problem-solving topics, quantity in multiplication, multiplication problem situations, units related to multiplication, and mental arithmetic. Table 3 also shows the respondents' age differences that researchers in this empirical study have studied. The categorisation was 6 to 7 years, 8 to 9 years and 10 to 12 years. When one views problem-solving subtopics, numerous studies have been conducted on children aged 10 to 12 years (Agostino et al., 2010; Fang et al., 2016; Gibbs et al., 2017; Schulz & Schulz, 2018; Yang, 2011). This problem-solving topic is often a subject that requires critical thinking among children (Schulz & Schulz, 2018). Thus, these 10 to 12-year-old children already have a substantial knowledge foundation before exploring more critical mathematical questions (Yang, 2011). Nevertheless, when one views the subtopic of multiplication quantity, many studies have examined children aged 6 to 7 years (Bakker et al., 2015 & Durham, 2012) and 8 to 9 years (Kaur et al., 2017 & Tasman et al.., 2011). Primary school syllabi issued on primary school textbooks in China have shown the use of large

quantities in calculations (Zhao et al., 2014). Similarly, primary school education in some countries heavily emphasises quantity in mathematical calculations at the primary level to form a substantial foundation before higher-level skills are introduced in mathematics (Ali & Mutawah, 2016). Nevertheless, there was only one article for each age level related to multiplication in the unit. On the contrary, as for the mental topic of arithmetic in multiplication, many articles studied children aged 10–12 years (Ali & Mutawah, 2016; Dubé & Robinson, 2010; Zhao et al., 2014). Children are believed to use mental calculations faster than adults (Zhao et al., 2014). Therefore, primary schools often use mental arithmetic, especially in the Chinese National syllabus, to establish critical thinking (Ding et al., 2016).

3.2.3 Research Methods

Table 4 shows the research methods adopted by the scholars in researching the concept of multiplication. These studies have used experimental methods, questionnaires, interviews, discussions and assignments. When research was done, most scholars carried out experimental methods to study this multiplication concept. However, two researchers adopted that method for the questionnaire (Huang & Witz, 2013 & Schulz & Schulz, 2018). Scholars also embraced questionnaires to investigate this concept of multiplication (Schulz & Schulz, 2018). In the interview method, only one researcher chose such an approach (Ali & Mutawah, 2016). This interview method was conducted on the parents of the students and the students to obtain sufficient data to obtain a more accurate study. Next, the discussion method was performed by three scholars, namely (Fang et al., 2016; Kaur et al., 2017; Zhao et al., 2014). In this method, the data were obtained easily because the respondents provided good cooperation, and empirical study could be done in more detail. Besides, the assignment methods were opted by four researchers (Agostino et al., 2010; Dubé & Robinson, 2010; Tasman et al., 2011; Yang, 2011). In applying this method, the scholars viewed the given assignment process as retrievable data. This assignment method was also an ancillary method for evaluating and collecting data to study the concept of multiplication.

3.2.4. Important Findings of the Concept of Multiplication

Important conclusions in the concept of multiplication were identified. Some critical findings need to be highlighted to funnel information and address the education system gaps, primarily in mathematics.

The first finding addresses the procedure in solving multiplication problems. In multiplication problem-solving, students are less proficient in understanding the steps in problem-solving (Schulz & Schulz, 2018). The study of Fang et al. (2016) employed bloom's taxonomy method in problem-solving. Nevertheless, in the study of Agostino et al. (2010), students are provided with a set of multiplication problems at two difficulty levels, namely the level of one step of solution and many steps in problem-solving. Pupils are familiar with problem-solving questions for memory processes. However, children with low working memory are limited and require a strategy and measures that they easily understand (Ven et al., 2012). Therefore, the use of concrete teaching aids is imperative in teaching students to count flexibly by using skip calculations as a multiplication strategy for students with difficulty (Gibbs et al., 2017). Thus, in solving multiplication problems, low-achieving students should be given a sound intervention in enhancing the concept of multiplication (Fang et al., 2016). Meanwhile, relatively skilled and intelligent students can advance their critical level in mathematics by furnishing real-world enrichment movements (Yang, 2011).

Next, the second finding discusses the concept of multiplication of quantity calculation. Calculating this quantity is paramount in the formation of mathematical foundations in students. In quantity calculation, most researchers utilised learning while playing, where students can learn new concepts and use the rules given in exploring and experimenting in games (Bakker et al., 2015). However, Durham (2012) confirmed that the quantity calculation applied to weak students despite providing additional classes still have insufficient knowledge, and each student is unique with their learning style, interests, family background, cognitive abilities and social and behavioural challenges. Behaviour is a challenge for educators. Furthermore, some students have difficulty converting repeated addition into multiplication sentences (Tasman et al., 2011). In directing this quantity calculation problem, technology has become one of the applications that help teachers teach quantity calculation where the use of iPad can be a practical tool for informal assessment to check students' acquaintance of mathematical concepts (Kaur et al., 2017).

The third finding reflects the multiplication problem situation. In understanding multiplication problem situations in mathematics, basic cognitive abilities of numerical operations and mathematical language problems have been prioritised in predicting verbal ability and reading accuracy and later determined as insignificant (Bjork & Bowyer-crane, 2013). The study of Paek et al. (2016) indicated that audio perception factors could change what students hear for multiplication problem situations, while kinesthetic perception factors can change the way students learn. Nevertheless, working memory can explain statistically significant variances in number writing, magnitude calculations and single-digit arithmetic but working memory differences have distinct relationships with different techniques (Simmons et al., 2012). At the same time, students' intuitive understanding of the principles can help them deal with concerns on each question (Sumarto & Galen, 2014). Furthermore, different qualities of children's understanding of multiplication problem situations involving broad measurements can also impact their strategies in problem-solving (Huang & Witz, 2013).

Furthermore, the fourth finding addresses units related to multiplication. Most students need to show a meaningful improvement in their abilities, and at the same time, teachers have also used mathematical facts in clarifying units related to multiplication (Durham, 2012). Thus, in using strategies and algorithms in multiplication and division, children are provided with various steps to solve counting problems where abilities in thinking about relationships between numbers have a significant positive effect on the use of strategies in multiplication (Schulz & Schulz, 2018).

The fifth finding comes under the concept of multiplication using the mental ability and pioneered by most countries in developing its education system (Ding et al., 2016). Teachers teach by using a memorising strategy called mental arithmetic. In this mental application of arithmetic, students can be categorised into three groups. The first group represents the group that memorises easily, the second group represents those who memorise moderately, and the third group represents those who memorise poorly (Ding et al., 2016). Each of these small groups will be placed under the care of specific teachers and lesson plans to improve student multiplication (Ali & Mutawah, 2016). Upon completion of one teaching and learning session, the teacher will record the abilities mastered by the student (Dubé & Robinson, 2010). The difference is the old concept of teachers teaching large quantities of students without categorising student abilities. When there are many students, sometimes students easily get distracted in understanding the concept of multiplication (Zhao et al., 2014).

4. Conclusion

Ergo, students' skills in multiplication operations for this systematic literature review represents a review of 20 identifiable relevant articles in the ERIC. The researchers posed two questions in reviewing this systematic empirical literature, namely (1) Lack of analytical studies on multiplication strategies, where most studies focus more on interventions in teaching and learning the topic of multiplication (2) Lack of literature review on the topic of multiplication. From the first question, 20 identified ERIC articles corroborated that the multiplication strategies used in the studies contain five paramount conclusions. The findings were multiplication problem solving, quantities in multiplication, multiplication problem situations, units related to multiplication and mental arithmetic. Each of these findings was elaborated on in the strategies used in the concept of multiplication.

The concept of multiplication in detail unravelled some of the strategies operated to improve the basics in mathematics. Most teachers used this foundation in mathematics in improving students' knowledge. However, the strategies utilised vary according to the needs of the students. Therefore, in deciphering this concept of multiplication, the researchers categorised it into four tables in this systematic literature review. Each table shows a close correlation with one another. Table 1 presents the concept of multiplication, Table 2 presents the countries that study the concept of multiplication, Table 3 presents types of subtopics of multiplication studied by age, and Table 4 presents the research methods used. Thus, the interpretation of the study's findings can also be found in the tables mentioned.

Nonetheless, it is indispensable to note that the data from these studies could not be generalised given that only 20 articles were identified from ERIC and the sources taken were also only empirical articles. Sources from books and thesis may also be helpful if prospective researchers wish to attend another systematic literature review. In addition, data from other sources such as Science Direct, Scopus, and Google Scholar may be collected and analysed for the study of this concept of multiplication.

Furthermore, the approaches taken in conducting these researches on the concept of multiplication highlights errors that students often make. The errors that students often make are procedural errors and steps in problem-solving. Children often forget and make the same missteps in doing multiplication calculations. Reinforcement in the concept of multiplication needs to be implemented by teachers in the classroom. This reinforcement is vital to improve the level of calculation skills and mastery in the concept of multiplication.
Furthermore, credit should be given to most researchers who examined the concept of multiplication because each concept made can be analysed and implemented in educational institutions. These researchers dissected the concept of multiplication with various strategies. Each of these strategies authorises teachers and students to indirectly innovate the teaching and learning system in schools. Therefore, researchers who intend to do further research on the concept of multiplication inspire to improve the education system.

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