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UNVEILING STRATEGIES: FOSTERING METACOGNITION IN PRIMARY SCHOOL PUPILS' LEARNING OF FRACTIONS

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Abstract— *Understanding the complexities of pupils' cognitive processes when dealing with fractions is crucial. When this process necessitates the cultivation of learners' metacognition (awareness of their own thinking processes), the challenge intensifies. Consequently, this study aims to address the existing research gap by investigating the extent to which teachers contribute to the development of pupils' metacognition in learning fractions. To conduct this investigation, a qualitative approach was employed, utilising data collected through interviews and subjected to thematic analysis. Six primary school teachers from Malaysia volunteered to participate, offering valuable insights into the pedagogical aspects of teaching mathematics, with a focus on fractions. The data collection procedure and instrumentation were strictly adhered to with ethical approval. Thematic analyses were conducted to discover appropriate and relevant strategies for promoting metacognition abilities across three dimensions: (1) Task: Teachers used visualisation to help pupils understand essential information. They also improved tracking progress using note-taking. (2) Strategy: Teachers actively monitored pupils' appropriate use of approaches and raised awareness of mistakes made in working out fractional problems; (3) Person or Individual: Teachers engaged pupils by providing ample opportunities for individualised learning. This study emphasises the importance of fostering learning opportunities among primary school pupils in mathematics teaching and learning. Consequently, teachers are urged to recognise the importance of creating multiple opportunities to engage pupils and build their confidence, thereby enhancing their metacognition.*

Index Terms—*learning of fractions, metacognition, primary school*

INTRODUCTION

Teachers have less burden to educate excellent mathematics pupils if they are independent and understand their own learning. For this purpose, pupils may need to experience a strong understanding of their own cognition. [1], [2]. Particularly, teachers need to show effortful development in improving pupils' cognition for greater comprehension and application of fractions. While pupils struggle to comprehend the complexities of fractions, building their inner perception is necessary to be resilient throughout their studies. For example, cultivating an inner perception of the importance of fundamental concepts of fractional acquisition on rational principles is necessary to build pupils' confidence and avoid math anxiety [3]. Hence, building up their awareness of their own abilities is necessary. Overconfidence and phobia of learning fractions without calibrating their own learning have been highlighted as pupils' weaknesses in learning [4]. Therefore, mastering fractions requires more than the acquisition of numerical operations; it demands a heightened awareness of the cognitive strategies employed by young learners. Metacognition, in this context, enables them to not only navigate the challenges but also reflect on and adapt their cognitive approaches [5]. Despite the acknowledged importance of metacognition in fraction learning, a research gap persists, particularly in understanding the role of teachers in fostering this metacognitive development.

LITERATURE REVIEW

Conceptual Overview of Metacognition in Mathematics Education

Metacognition, a key concept in guiding own learning and cognition development, is critical for effective learning [5]. It underscores learners' processes of planning, monitoring, evaluating, and changing their learning behaviours, and it is crucial in the acquisition of learning methods [6]. Metacognition is frequently assessed in two dimensions: metacognitive knowledge (associated with planning, monitoring, and evaluation) and metacognitive regulation (associated with changes in learning behaviours) [7]. Metacognitive knowledge, which includes the ability to organize, monitor, and assess one's learning processes, acts as a guidepost for learners, directing their cognitive activity. In tandem, metacognitive regulation entails the adaptive ability to adjust one's own learning activities in response to metacognitive insights.

Teaching metacognition in the classroom has been shown to improve pupils' performance in assessments [8], [9]. Beyond mere mathematical knowledge and techniques, pupils must acquire metacognitive skills to bolster their performance in mathematics. Nevertheless, researchers argue that training in mathematics metacognitive strategies is urgently needed for school pupils [10]. However, there is a noticeable gap in research regarding how pupils engage their cognitive skills when solving mathematics problems. It has been emphasised that young children have thinking limitations of cognitive thinking [5]. Thus, understanding pupils' thought processes and potential misconceptions is essential for educators to effectively integrate metacognition into their teaching.

Metacognition in the Context of Fraction Learning

Mathematics, being a cornerstone subject for the development of science and technology, holds paramount importance in school education. Numerous studies have highlighted the significant positive correlation between metacognitive skills and mathematics performance [11], [12]. Therefore, it is increasingly emphasised that mathematics educators incorporate metacognition skills into their teaching and learning strategies [13], particularly the topic of fractions. Teachers themselves should reflect metacognitively on the means to improve metacognition in pupils while teaching fractions. Nevertheless, teachers will not be able to perform this if they are not provided with sufficient training. In addition to imparting mathematical knowledge and techniques, pupils should acquire metacognition skills to enhance their performance in mathematics. Interestingly, pupils can be trained to improve mathematical performance through metacognitive skills such as monitoring or regulation [14].

However, pupils often need to be more aware of their own understanding when solving complicated mathematics problems that require fundamental mathematical topics, such as fractions. A key contributing factor to these challenges lies in pupils' failure to monitor their own learning within their knowledge effectively [9], [14]. Consequently, there is a pressing need for pupils to comprehend not only what they are learning but also how they can communicate within their own abilities in the learning process. To address this issue, the incorporation of metacognition into mathematics education has emerged as a vital approach. Understanding how pupils can apply metacognition to independently master fractions, more concerns, and engagement in class, as well as observation, deemed essential in the twenty-first century classroom. Unfortunately, the integration of metacognition into mathematics teaching and learning, particularly concerning fractions, may need more attention, requiring the discovery of strategies.

This study seeks to address this critical research gap by delving into how teachers assist pupils to engage in metacognition while solving fraction problems. Understanding the challenges of pupils' cognitive processes when dealing with fractions is pivotal. Such insights serve as valuable references and strategies for teachers to influence students' effective learning. It provides opportunities for teachers' detailed understanding of pupils' logical reasoning and areas of difficulty before integrating metacognition into the advancement of more complicated topics. A study revealed that metacognitive mathematics instruction should be planned, and the strategy that is introduced should be directly targeted at improving the monitoring and regulation of pupils' thoughts when dealing with mathematics problems [15]. With metacognition, pupils' responsibilities to bring up excellent learning and achievement.

An investigation of a survey of notable articles found that metacognitive studies are predominant in recent research work. Nevertheless, it shows fewer publications on the context in developing countries. [16]. Hence, there is an urgent need to focus on individuals' education development to meet the quality of education and ensure equitable education. For this purpose, , teachers' understanding of pupils' metacognition skills provides opportunities for development.

This is because conscious reflection enables pupils to develop the ability to choose the most appropriate strategies for learning concepts and solving mathematics problems.

By exploring the role of metacognition in fraction learning, this study aims to contribute substantively to the field of mathematics education, ultimately facilitating more effective teaching strategies for fractions and enhancing pupils' overall mathematical proficiency. Particularly, this study aims to investigate the extent to which teachers contribute to the development of pupils' metacognition in learning fractions. For this purpose, the research question is, "To what extent do teachers develop pupils' metacognition in learning fractions?"

METHOD

This study collected teachers' perceptions pertaining to their pupils' metacognition while studying fractions. A qualitative approach was employed to collect data via interviews. A total of six mathematics teachers engaged in these interviews, utilising data collected through interviews and subjected to thematic analysis. Six primary school mathematics teachers from Malaysia volunteered to participate, offering valuable insights into the pedagogical aspects of teaching mathematics, with a focus on fractions. They were from the northern part of Malaysia. Hence, convenient sampling was implemented. The use of convenience sampling was acceptable because the study's inclusion criteria were based on teachers' perceptions about pupils' metacognition, which was accessed in the research setting [17]. The participants had also agreed to their participation. Ethical considerations were strictly adhered to, and the research ethics committee approved the data collection process.

The interview protocol was organised to align with the research questions, namely, "To what extent do teachers develop pupils' metacognition in learning fractions?" Three aspects of metacognition were in focus. The interview questions pertaining to the three aspects, namely metacognitive task, metacognitive strategy, and metacognitive person, are listed in Table 1. Specifically, metacognitive task describes knowledge pertaining to a proposed task that is available to a learner; metacognitive strategy refers to a strategy pertaining to a method that is within a learner's awareness; and metacognitive person refers to an individual's understanding of how they learn [5]. The interview data were analysed thematically within the specific aspects of metacognition.

Table 1. Samples of interview questions

Metacognitive knowledge	Items
Strategy	To what extent are your students aware of the strategies they use when they learn fractions?
	Are your students aware of how well they are doing while they are learning something new about fractions? Could you explain it?
Task	To what extent do your students know what the teacher expects them to learn in fractions?
	To what extent do your students think about what they need to learn before they start working on fractions? How do you assist them on this matter?
Person	To what extent do your students know when they understand fractions? Do they realize their own understanding?
	How do you gauge your students' interest in learning fractions? Do they learn more because of their interest?

FINDINGS

The interview transcripts were analysed according to three aspects (metacognitive task, metacognitive strategy, and metacognitive person). Table 2 summarises the findings. The findings of the study revealed several strategies employed by teachers to nurture pupils' metacognitive abilities across three dimensions: (1) Task: Teachers captured pupils' focus on essential information within educational materials through visualization. Simultaneously, they reinforced content by monitoring note-taking methods and tracking progress; (2) Strategy: Teachers actively monitored pupils' approaches and identified their mistakes to enhance the utilisation of appropriate strategies in handling fractions; (3) Person or Individual: Teachers engaged pupils and provided ample opportunities for individualised learning.

Finding 1: Metacognitive Task

Teachers captured pupils' focus on essential information within educational materials through visualization. Simultaneously, they reinforced content by monitoring note-taking methods and tracking progress. They believed that it is essential for pupils to be aware of the important contents of fractions as described by T1, T2, and T4. It was proven that pupils who were good at fractions knew the contents well, as depicted by T4. Teachers needed to keep an eye on pupils who were not aware, as T5 described. Among the assistances are getting pupils' attention on important information in the learning contents via visualization. Nevertheless, teachers frequently provided solutions and reminders. T1 and T6 agreed on it with the following statement.

T1: "…**intelligen**t students are **aware** of what they are learning, whereas some weaker students only take in what is said in class. They have no idea what fractions are… I have to **monitor** each student and help those who need it… I'll explain where the important details are before writing them on the board… **I will show them how to get the right answer…** I frequently draw a diagram to help the students better comprehend what the **fraction represents…**"

T2: "….my students are **unaware of the lessons** I want them to learn about this subject…"

Table 2. Summary of the findings

Metacognition	Themes	Description
Task	Need guidance	Monitor and guide pupils according to the learning contents.
	Instrumental knowledge	Pupils preferred solving problems using instrumental knowledge.
Strategy	Students' approaches	Monitor and guide pupils to foster their confidence in using different strategies.
	Correcting strategies	Keep observing pupils' difficulties in applying correct strategies, such as detecting problems in conducting addition.
Person	Engage	Engage pupils in learning.
	Opportunities	Provide multiple opportunities for classroom discourse.

T4: "…student is **aware** of what they will learn about fractions that day."

T5: "… Students tend to pay less attention to crucial information during a typical learning process, so I have to **keep an eye** on them to keep them focused."

T6: "… teachers must always repeat important information that must be remembered."

Besides, teachers emphasised the content from time to time, such as after each lesson. They also closely monitored their pupils in taking notes as well as their progress while learning, as described by T3 and T2.

T3: "…At the conclusion of the lesson, I will ask students to respond to a few questions… **I advise them to take notes because not all of the information is contained in the textbook…"**

T2: "… I will divide my class into two groups: those who can answer fractional questions on their own and those who require assistance…"

In emphasising the contents, the teachers were aware that their pupils failed to use representation, using instrumental knowledge, namely procedural knowledge, in solving problems. They were weak in operations such as division, as described by T2, T3, and T6.

T2: "… Students who are good at math will continue to use standard calculations to respond to questions…"

T3: "……, because fractions are challenging to represent in diagrams, they prefer to multiply and divide fractions using conventional… **struggling with fractional division…"**

T6: "…. My students **struggle** with equating denominators in fraction addition and subtraction.."

Pupils were struggling to comprehend the reason for going through the procedures of fractional operations; hence, they might face some problems while working on it. As a result, depending too much on instrumental knowledge deterred them from developing metacognitive tasks.

Finding 2: Metacognitive Strategy

Fractions are difficult. Approaches used among pupils were not consistent. Many pupils were not confident in applying approaches taught by teachers. Hence, the teachers provided opportunities to all pupils to let them apply their own familiar strategies such as representations or visualisation to develop their metacognition. On the other hand, closely monitor weak pupils were required too. Their efforts were shared (T1 and T3) as below.

T1: "… students enjoy exploring many strategies while also feeling at ease using a certain strategy….if students are still confused, I will use a different question with the same strategy…."

T3: "… I might advise those who learn best visually to use drawings…"

Teachers were aware of the consequences if pupils failed to use different strategies. Metacognitive knowledge of strategies is essential since pupils would fail to communicate through mathematical questions if other related knowledge and methods were required. Failure in coordination caused low confidence in working out fractions. T2 brought up these issues:

T2: "…if the question asks about discounting 50%, students who memorize the process will not be aware that the answer uses fractions… Most pupils are not aware that they are using the proper method. They simply follow the teacher's instructions… lack confidence or believe the result they get using that strategy is wrong or illogical, they will revert to the strategy…"

T3: "…Every time a student says "oooo" I know that they are aware of whether or not the strategy… students frequently struggle with fraction-related questions…"

T1, T4, T5, and T6 supported T2 on pupils' less confidence resulting in carrying out wrong procedures in addition:

T1: "… students continue to add the numerator and denominator when adding fractions"

T4: "… 10% of students are confident in their strategies…."

T5: "… Their level of confidence is based on how well the strategy yields the correct answers. …"

T6: "… Sometimes the strategy they use is correct, but their confidence is shaken because they do not understand the basic concept of multiplying numbers…"

Finding 3: Metacognitive Person

It was found that pupils who were aware of personal performance used to consult teachers, but for moderate awareness pupils used to ask their peers as described by T1:

T1: "…Particularly for students of average intelligence, they are more likely to ask their classmates…"

Enhancing metacognition for self-awareness is essential since interest of learning difficult topic comes from achievement:

T3: "… if students comprehend, they will be interested. They will lose interest, start doing other things, and lose focus…"

Teacher T6 found challenging to get pupils' interest in learning fractions. Added by T5 that the pupils are forced to study this topic. Their interest encourages them to be involved in exploring task and strategies, develop a clear way of learning and improvement.

T6: "… The more challenging aspects of fractions will excite students who are interested in fractions because they want to explore…"

T5: "… The majority of my students are forced to learn fractions, not because they want to…"

Even though they might not interest, engaging them in class should be done to motivate them so that they were not totally lost as described by T4.

T4: "… If they get lost in class, they will be depressed and unmotivated.

Hence, creating opportunities to engage them is essential since T3 highlighted engagement through interest is also his responsibilities in assisting them.

T3: "… if they comprehend the subject of this fraction, they will be more interested in learning…"

DISCUSSION

The study's findings show teachers were aware of pupils' weaknesses in metacognitive tasks since they had excessive dependence on instrumental knowledge, making less connection to the learning contents. The study highlights that excessive dependence on instrumental knowledge can hinder metacognitive tasks. In learning mathematics, there is no doubt that pupils should have instrumental understanding in working out solutions. It enables them to successfully answer according to any procedures required and motivates them to work further [18]. Nevertheless, meaningfully gaining mathematical knowledge should be focused on since mathematical knowledge is developed from understanding [19].

This awareness prompted them to use a sophisticated strategy to encourage metacognition among primary school pupils who were studying fractions. By employing visualisation techniques, the teachers found a way to assist the pupils in their learning. Using instructional materials was recognised as an effective way to enhance the learning process [20]. Furthermore, their commitment to evaluating content is evident in their observation of note-taking methods and monitoring of progress. Hence, teachers' guidance, engaging pupils in the learning process, and applying visual aids are essential to the learning process [21]. The learning process greatly contributes to strengthening metacognition.

Besides, the findings indicated that teachers observed a lack of consistency in the strategies used by the pupils. It demonstrated a prevalent lack of confidence among pupils in utilising the strategies taught by lecturers. In response to this problem, teachers took an active role by providing students with chances to utilise their own known strategies, such as representations and visualisations, in order to foster metacognition. This is consistent with the belief that enabling pupils to utilise strategies that they are familiar with might improve their comprehension and self-assurance, provided that they are experiencing good emotions [22], [23].

However, it is crucial to possess knowledge of the correct and diverse array of strategies. The significance of metacognitive knowledge in employing strategies is emphasised, as pupils may encounter difficulties in successfully communicating during mathematical problem-solving if they lack a diverse range of strategies. This aligns with prior studies indicating that confidence is strongly associated with the ability to effectively coordinate different mathematical strategies. Specifically, using multiple ways of representation while solving mathematics problems gives advantages [24]. Increasing their active participation in the learning process will also cultivate their personal intuition in mathematics. As a result, it is important to provide support for the creation of learning opportunities in order to foster the development of individuals' skills and, consequently, improve metacognition, especially in metacognitive person.

CONCLUSION

Developing pupils' metacognition in mathematics education is a difficult task due to their limited comprehension and deficiencies in the mathematical procedures. Teachers bear significant duties in creating opportunities across multiple domains, such as providing guidance, fostering engagement, and utilising visual aids. This study offers valuable insights for educators regarding the future direction of mathematics instruction. It emphasises the importance of teachers taking on active roles to actively engage pupils rather than relying too heavily on instrumental knowledge alone. Besides, this study sheds light on crucial aspects of fostering learning opportunities among primary school pupils in the realm of mathematics. Consequently, teachers are urged to recognise the importance of creating multiple opportunities to engage pupils and build their confidence, thereby enhancing their metacognition.

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