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Unveiling the Link between Metacognitive Skills and Mathematics Performance: A Correlational Study in Grade X

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Abstract

Although it has always been a required core subject in Bhutanese schools, underachievement in mathematics regularly shows that the requirement has very little impact on students. This study's major goal was to look at the connection between mathematics performance and the metacognitive skills of grade X students. This study used 347 grade X students (M = 162, F = 185) from one of the schools in Sarpang Dzongkhag and a quantitative correlational survey design. The level of students' metacognitive skills was evaluated through a modified Metacognitive Awareness Inventory (MAI, whilst their mathematics achievement was evaluated through the Mathematics Performance Test (MPT). Students in grade X were found to have a high degree of metacognitive skills (M= 3.54, SD=.42). While the correlational analysis showed a weak but significant positive correlation between students' metacognitive skills and mathematics performance. The outcome also showed that students' metacognitive skills are a statistically significant predictor of their mathematics performance. The findings suggest that metacognition be taken into account to aid students' learning of mathematics. Additionally, a similar study with a different research methodology and approach is advised.

Keywords: *Mathematics Performance Test (MPT), Metacognitive Awareness Inventory (MAI), Metacognitive knowledge, Metacognitive regulation, Metacognitive skills*

1. Introduction

In Bhutanese schools, mathematics has always been taught as a fundamental and required topic. However, research projects like the National Education Assessment [29] and Education Without Compromise [17] as well as Bhutan's Annual Status of Student Learning [38][39][40] and The Quality of School Education in Bhutan [39] carried out by the Ministry of Education (MoE) and Royal Education Council (REC), among others, have shown that the subject's status as a requirement has done very little to encourage and motivate Bhutanese students to pursue their education in more depth. Additionally, international studies like the Trends in Mathematics and Science Study (TIMSS) and the Program for International Student Assessment (PISA) have shown that mathematics learning and achievement in students is a worldwide issue [30].

According to the Pupils' Performance Report (PPR) BCSEA [4][5], it was reported that the performance in mathematics by Bhutan Certificate of Secondary Education (BCSE) is

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comparatively lower than in other subjects. BCSEA [4] reported that the mean score of BCSE (Grade X) students in mathematics was 50.75% with a similar pattern in 2020 [5] with 52.02%. Moreover, BCSEA [3] also revealed that Bhutanese students only scored 38.84% in PISA-D Mathematical literacy, which is significantly below reading literacy (45.3%) and scientific literacy (45.1%). A similar situation was observed in Sarpang Dzongkhag where this study was carried out. According to BCSEA [5], the mean score of Sarpang Dzongkhag in mathematics was 46.44%, and the school where this study had taken place, in particular, scored only 43.09%, which was lower than the national mean score (52.02%).

However, on the brighter sight, a significant number of studies have proved that metacognition is an essential component of successful learning [11][32][36][50][53]. Additionally, some researchers have concluded that there is a reasonable relationship between students' metacognitive skills and their degree of academic success [10][15][37]. Metacognition skills can be defined as a person's knowledge of their thought processes and their capacity to regulate them [14][18][22][34].

Though there are a few kinds of research conducted in Bhutan to understand the cause of underachievement in mathematics performance, nevertheless, no research has been conducted to understand the relationship between students' metacognitive skills and their performance in mathematics. Therefore, this research aims to understand the connection between students' metacognitive skills and their performance in mathematics subject.

1.1. Purpose of the study

There are two main purposes of this study, the first purpose is to determine the level of the grade X students' metacognitive skills and then understand the relationship between students' metacognitive skills and students' mathematics performance.

1.2. Research questions

The following research questions are used to guide this study:

1. What degree of metacognitive skills do students in grade X possess?
2. Is there a significant relationship between metacognitive skills and Mathematics performance?

1.3. Significance of the study

The goal of the research is to gauge the metacognitive proficiency of grade X students and determine whether there is a connection between math achievement and metacognitive proficiency. The results of the research could be used to explain to readers how crucial metacognitive abilities are for learning mathematics. Additionally, it is anticipated that the study will serve as the starting point for further investigation into the role of metacognition in education. In addition, parents and educators may decide to implement the advice gleaned from the findings, which could improve students' performance. In a similar vein, the study may act as a guide for administrators on what areas of the school curriculum teachers should stress to boost students' performance. Finally, the study may aid the researchers in understanding crucial facets of the educational process that many other researchers were unable to investigate.

2. Literature review

Metacognition has been defined as "knowing about knowing"; it is the awareness individuals have of their thought processes [8]. The word metacognition was first used by Flavell [18], who defined it as "cognition about cognition" or "thinking about thinking." The study of "how we think about our thinking to develop learning strategies" is referred to as metacognition [23]. A person's ability to comprehend and manage their cognitive function is aided by metacognition, a regulatory system. This has led to the understanding that metacognition skills can be referred to as a person's knowledge of his or her thought processes and capacity to exert control over those processes [14][18][22][34]. Therefore, being conscious of one's thought process and directing it toward learning can be referred to as metacognition.

Young and Fry [54] researched to examine the relationship between metacognitive skills and academic performance in 178 higher education students. A correlational analysis discovered a substantial positive correlation between metacognitive skills and student academic success. Furthermore, several pieces of literature have been found that concluded metacognitive skills are a necessary component of effective learning [11][32][36][50][53]. Furthermore, some researchers asserted that there was a reasonable relationship between students' levels of academic achievement and metacognitive skills [10][15][37].

The relationship between metacognition and mathematical performance was also demonstrated in several bits of literature. For instance, Ozsoy [33] carried out a study to look at the relationship between fifth-grader pupils' achievement in mathematics and their metacognitive abilities. 242 students made up the participating group. The findings showed a substantial and advantageous link between metacognition and mathematical proficiency. The research also revealed that metacognitive abilities and knowledge could account for 42% of the overall variance in math achievement. From this, it can be inferred that metacognition is crucial for comprehending successful mathematical performance [25].

Furthermore, according to numerous researchers, metacognition is crucial for achievement in mathematics [6][13][16][45]. According to Artz and Armour-Thomas [2], the primary cause of students' inability to solve problems is that they are unable to keep track of their thoughts as they do so. Therefore, metacognition might influence how kids acquire math or help them do better in math. Students may find it crucial to learn how to control and regulate the actions and processes taken to achieve problem-solving objectives. Successful academic students reportedly develop the self-awareness necessary for employing efficient problem-solving techniques [19]. Additionally, Desoete's research [14] found that 37% of mathematical problem-solving success is attributable to metacognitive knowledge and abilities. This demonstrates the critical role metacognition plays in intelligence and cognition and how it has a big impact on academic performance.

Additionally, some studies [26][31][32][34][50][53] indicated that using instruction activities to build metacognitive skills can result in positive and significant improvements in the academic achievement of children. As a result, academic ability can be accurately predicted by using metacognition. Not always, though, is this the case. The relationship between metacognitive abilities and academic achievement has also been shown in some research to be neutral or even negative [47].

Schoenfeld [44] has drawn attention to the fact that education procedures typically ignore metacognition. He claimed that quantitative understanding and metacognitive abilities are interdependent. Lack of growth in mathematical and metacognitive abilities is one of the most prevalent issues seen in pupils' at all educational levels. Since studies that foster understanding are not given enough weight in mathematics education, situations and procedures are emphasized more often than they should be. The reason why pupils struggle in math classes is due to this [44].

Many studies have explored the importance of metacognitive skills and their importance in enhancing students' academic performance. However, almost all of the studies are conducted in Western countries that have different cultures, environments, and mindsets. What would Bhutanese students think about metacognitive skills, and how is it important for Bhutanese students in enhancing mathematics performance?

3. Methodology

Planning and methodical inquiry are essential to the research strategy. Quantitative correlational survey methodology is used in this research. A quantitative correlation survey design is used to investigate the relationships between and among factors that are crucial to research questions and hypotheses [12]. The Metacognitive Awareness Inventory (MAI) survey questionnaire was specifically modified for this research to use as a tool for assessing students' metacognitive skills. On the other hand, the Mathematics Performance Test (MPT) was used to assess pupils' mathematical proficiency.

3.1. Participants

According to the researcher's convenience, the study was carried out in one of the secondary schools in Sarpang Dzongkhag, in the southern portion of Bhutan. The school's entire grade X pupils made up the study's population. There were 352 pupils in the grade X class, divided into 9 sections, with 166 males and 186 females. The entire grade X pupils was chosen to participate in the survey and receive the questionnaires to collect the quantitative data using purposive total population sampling. Purposive sampling, according to Creswell [14], is effective when the researcher already has knowledge of the particular individuals or events and purposefully chooses some of them because they are thought to be the ones that could yield the most valuable data. It is also possible to use the purposive sampling strategy to extract detailed and rich information from a typical sample [12]. This sampling method was also thought to be appropriate for the research in light of all these benefits.

3.2. Instruments

An adapted form of the MAI from Schraw and Dennison [46], a pre-made survey questionnaire, was used to assess students' metacognitive abilities. Following extensive literature reviews and professional advice, 52-item survey surveys were contextualized and changed by including learning-related questions in the items. For instance, the items "I organize my time to best accomplish my goals" and "I ask myself periodically if I am meeting my goals" were changed to "I ask myself periodically if I meet my learning goals" and "I organize my time to best accomplish my learning goal." Some of the items underwent similar modifications to make them more student-friendly and readable.

Further, items were rated on a five-point Likert scale to measure students' agreement on the items, which ranges from "1-Strongly Disagree" to "5-Strongly Agree". However, the mean score of the five-point Likert Scale was interpreted using Table 1 adapted from Brown [7]. The interpretation was used to describe the level of students' Metacognitive skills.

Table 1. Interpretation of Likert-scale

Mean Score	Metacognitive Level
4.21 - 5.00	Very High
3.41 - 4.20	High
2.61 - 3.40	Moderate
1.81 - 2.60	Low
1.00 - 1.80	Very Low

The MPT was developed by the researcher to measure students' performance in mathematics. The test consists of ten questions. Standardized test questions were prepared from the grade X mathematics textbook "Understanding Mathematics" published by the Department of Curriculum Research and Development, Ministry of Education (MoE). MPT consists of ten problem-solving questions prepared from Unit I: Matrices and Networks, and Unit II: Commercial Mathematics based on the guidelines of the curriculum for grade X. The questions were set for 30 marks. Later the score from the MPT was administered to examine the relationship between students' performance in mathematics and students' metacognitive skills.

3.3. Reliability of the instrument

To investigate the degree of metacognitive skills, the MAI was chosen. One of the schools from the district participated in the survey's trial run. The MAI's total Cronbach's alpha was .92. According to a Cronbach's Alpha score of.70 or higher is usually regarded as acceptable. Similarly, the test-retest dependability test was used to determine the MPT's reliability. The test items' Cronbach's alpha (.86) score showed that the instrument was trustworthy for the study.

3.4. Data analysis

The data from the quantitative survey (MAI) and Mathematics Performance Test (MPT) were analyzed concurrently because the research used a quantitative correlational survey design. To begin with, a descriptive study of MAI was done to determine the degree of metacognitive skills. Then, inferential statistics were used to look into the connections between students' mathematical success and their metacognitive skills, such as the Pearson correlation and linear regression analysis test. Furthermore, Table 2's modified Sugiyono [48] rating scale was used to understand the relationship between students' metacognitive skills and math performance. Tables and numbers were also used for readability, comprehension, and ease of interpretation. The Statistical Package for the Social Science (SPSS, version 25) was used to evaluate all the data gathered from the MAI survey questionnaire and MPT.

Table 2. Interpretation of correlation

Correlation Coefficient Value (r)	Interpretation
0.00 – 0.25	Weak
0.26 – 0.50	Moderate
0.51 – 0.75	Strong
0.76 – 1.00	Very Strong

4. Results and discussion

For this study, a total of 352 survey questionnaires were administered to 352 grade X students, however, 347 questionnaires were returned giving a response rate of 98.57%. It was a purposive total population sampling where all the grade X students from the particular school were selected for the study. On the other hand, 1.43% of the students could not participate in the study, which comprised three students who could not respond to the survey as they were absent during the survey, and two other students' responses were considered invalid as there were many items not attempted. It was found that there were more female participants (N=185) which comprised 53.3% than males (N=162) which comprised 46.7%.

4.1. Level of students' metacognitive skills

The results (Table 3) from the descriptive analysis of the survey questionnaires (MAI) showed that the grade X students possess a high level of metacognitive skills (M = 3.54, S.D = .42). The findings from this study corroborated the findings of the study done by Garzon [21]. They investigated the relationship between metacognitive skills, gender, and level of schooling in high school students. They involved 319 high school students from grades 6 to 11 from one of the private schools in the city of Bogotá, Colombia. It was found that students from grades 6 to 11 possess a high level of metacognitive skills. Further, the result is echoed by Abdelrahman [1] who performed the study with grade XII students from Kersana Brebes Public Senior High School, and college students of Ajam University, UAE, respectively. On the other hand, the study by Ozsoy [33], carried out in six public primary schools in Zonguldak-Eregli, Turkey, found that fifth-grade primary school students possess a below-average level of metacognitive skills. This result contradicts the current findings. However, if the works of literature obtained from different researchers are compared along with the current study, it could be partly assumed that the level of metacognitive skills relates to the development of the child. This hypothesis is supported by research by Flavell [18] and Schneider and Lockl [43], which found that education and age-specific growth play important roles in metacognitive development. This presumption is further supported by several studies that found that people with more education have superior metacognitive skills [43].

Table 3. The overall level of metacognitive skills

	N	Mean	Std. Deviation	Level
Metacognitive Knowledge	347	3.58	.43	High
Metacognitive Regulation	347	3.49	.50	High
Metacognitive Skills	347	3.54	.42	High

Note: 4.21 - 5.00 (Very High) 3.41 - 4.20(High) 2.61 - 3.40 (Moderate) 1.81 - 2.60 (Low) 1.00 - 1.80 (Very Low)

4.2. Metacognitive skills and mathematical performance of students

The strength of the connection between students' metacognitive skills and mathematics performance was assessed using linear regression analysis. A significant weak positive correlation between students' metacognitive abilities and mathematics achievement was found in Table 4 ($r = .133$, $p \leq .05$) at a 95% confidence level. Furthermore, this model demonstrated that students' metacognitive abilities accounted for 1.5% of the variability in their mathematics achievement. According to the model's beta value of 1.192, math ability should significantly improve by 1.192 points for every point raised on a test of metacognitive skills.

The results demonstrate a significant relationship between student metacognitive abilities and mathematics achievement (p =0.05) at a 95% confidence level.

According to the Pearson correlation (r =.133), there is a marginally positive correlation between students' mathematical achievement and their metacognitive abilities. Additionally, the current study's simple linear regression result demonstrates that students' metacognitive abilities can account for 1.5% of the variation in mathematics achievement. The outcome is in line with earlier research findings, which showed a significant positive relationship between metacognitive abilities and mathematical performance [24][47][49][54]. Therefore, it can be inferred to some extent that metacognitive abilities are crucial for the growth of students' mathematical knowledge and for improving mathematical success. According to Young and Fry [54], students who apply metacognitive principles are thought to have exceptional academic success.

However, the current study presented that only 1.5% of the variation in mathematics performance could be explained by metacognitive skills, which is very less compared to the findings of the studies conducted by Doesoete [14], and Lucangeli and Cornoldi [25]. Lucangeli and Cornoldi [25], found that students' metacognitive knowledge and skills accounted for 37% of the variance in math success, Doesoete [14] found that 42% of the variation in math achievement could be accounted for by metacognitive skill. These major differences in the effect size of the metacognition could be due to ignorance of metacognition in our education society. This assumption is supported by Schoenfeld [44], who emphasized that metacognition is generally ignored in education processes and stated that metacognition skills and mathematics is inseparable entities.

Accordingly, the researcher thinks that metacognitive skills should be taught as part of the teaching and learning procedures in the school system. This is consistent with several studies that found that teaching students metacognitive abilities may enhance their academic performance [9][32]. Additionally, teachers should have access to the various methods for enhancing metacognitive skills, including "IMPROVE" [27][28], "metacognitive problem-solving activities" [32], and "reciprocal teaching" [35], so that they can train their pupils in these techniques.

Table 4. Linear regression between metacognitive skills and mathematics performance

Dependent Variable	Independent Variable (Predictor)	R	R Square	Df	F-value	P-value	Beta Score	Sig
Mathematics Performance	Metacognitive Skills	.133*	.018	345	6.195	.013b	1.192	.00

5. Conclusion and recommendation

The main goal of this research was to ascertain whether math performance in grade X students is correlated with their metacognitive abilities. In conclusion, the extent of metacognitive abilities was assessed, and the association between metacognitive skills and mathematical achievement among pupils was also explored.

The study's conclusions showed that kids in grade X generally possess a high level of metacognitive abilities. The study also concludes that students' metacognitive skills and mathematics performance are significantly correlated. The study also discovered that students' metacognitive skills are an important predictor of their mathematics success. Therefore, teachers, school leaders, and the school system may explore adopting metacognition strategies to enhance students' performance. However, since, the results of the study are solely based on self-report metacognition questionnaires. Future researchers and teachers can explore different assessment techniques, such as think-aloud procedures and systematic behavior observation to authenticate the relationship between metacognition and students' performance. Moreover, to fully comprehend the relationship between students' metacognition and mathematical performance, additional research can be conducted using a mixed-method approach, quasi-experiment, or action research.

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