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Factors Affecting Bhutanese Secondary School Students' Ability in Solving Mathematical Word Problems: A Case Study

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

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Abstract

Mathematical word problems are part of the school curriculum and are taught at all levels of education in Bhutan. However, it poses difficulties for many students because of the complexity of the solution process. There are various factors that affect students' ability to solve mathematical word problems. Hence, this study was conducted to investigate the factors affecting Bhutanese secondary school students' ability to solve mathematical word problems. This study employed a qualitative case study approach. Data was collected through semi-structured interviews, classroom observations, and document analysis. Four mathematics teachers and four students were selected as participants based on purposive sampling. The data were analyzed using thematic analysis. The findings revealed that factors such as language proficiency, reading skills, and contextual understanding affect students' ability in solving mathematical word problems. Moreover, the language proficiency of students, as well as teachers, was the most important factor for solving mathematical word problems. The study recommends the Ministry of Education places more importance on reading activities across schools in Bhutan to enhance language proficiency.

Keywords: Bhutanese students; contextual understanding; English language; language proficiency; mathematics language; reading skills; word problems.

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Definitions

For purposes of clarity, these terms which occur frequently in the study are defined as following.
Secondary school in this study refers to a school that has classes 7 to 12.
English as a medium of instruction in this study refers to a language used only in teaching and learning and not the mother tongue.

Abbreviations

BCSEA	*:Bhutan Council for School Examination and Assessment.*
CAPSD	*:Curriculum and Professional Support Division.*
DEO	*:Dzongkhag Education Officer.*
ESL	*:English as Second Language.*
MoE	*:Ministry of Education.*
NCTM	*:National Council of Teachers of Mathematics.*
NEF	*:National Education Framework.*
PISA-D	*:Programme for International Student Assessment Development.*
TPDP	*:Teacher Professional Development Program.*

1 Introduction

Mathematics education in Bhutan starts with the primary mathematics curriculum, which provides the bases for various mathematics courses at higher levels. As a subject, mathematics is taught compulsorily till class 10. The mathematics syllabus is based on the school mathematics framework [1], which emphasizes the need for a balance between acquisition of conceptual mathematics knowledge, processes, and attitudes [2]. This curriculum framework encapsulates that the thrust of mathematics education in Bhutan is to prepare students to be competent and effective future citizens to produce a mathematically competent society [1]. So, Peer pointed out [2] its ultimate aim is to motivate students to learn and value mathematics as an important tool in helping them to explore their natural world and developing critical problem-solving skills and communication skills for their life.

More recently, Teacher Professional Development Program (TPDP) [3] discussed, to enrich and improve the process of education, the government of Bhutan has put all its efforts by introducing transformative pedagogy into school education. Teachers are now equipped with various strategies to deliver the lesson in the class. However, National Education Framework (NEF) [4] pointed that learners' achievement is typically low in mathematics The reason for low scores in mathematics lies in the fear of mathematics and the methodology of teaching, especially chalk-and-talk method and memorizing out of context.

The majority of the students struggle with the mathematics, in particular with 'word problems'. It was found in Bhutan PISA-D national report that students performed better in items requiring lower cognitive skills, however, there is a significant gap in performance in more demanding task [5].

1.1 Problem statement

Mathematics play important role in our daily living. It is the subject that deals with problems that involve a process of analysis, computation, and other mental skills. Mathematics are more than counting, measuring, and computing. It enhances the mind to think critically and analytically. Often, mathematics is believed to have more numbers and symbols representations. However, the reality is there is a large component of word problems that require students to use their language knowledge and skills. Pfannenstiel defined [6] defined mathematical word problems are a combination of numbers and words in which students apply mathematics instruction in the context of a problem solving. It is designed to help students apply mathematics concepts to

real-life situations. Yet, mathematical word problems pose difficulties for many students because of the complexity of the solution process.

Word problem solving is a real test in mathematical abilities. It concerns understanding of the problem which practically demands reading comprehension. It also requires the proper operation formula that is needed to get what is required. It also requires the proper operation of the numbers or expression involved. These are some of the common steps in solving word problems.

It must be noted that in every problem there is a solution. It is then a challenge for every problem solver to find some ways and measures to find the solution of the problem. Any student who lacks knowledge and skills in solving word problem in mathematics in general (algebra, arithmetic, geometry, etc) will find difficulties to arrive the correct solution.

Students have varying ability in learning mathematics. Some students can use calculation algorithms successfully whereas they are not able to solve word problems which need the same algorithms. Therefore, they need to fully comprehend the word problem before they attempt to solve it. The reason for such inability is that solving word problems tend to be complicated in part because of their descriptive language. Students often don't understand what exactly they are being asked, especially when the problem includes abstract concepts [7].

2 Literature Review

Several definitions of mathematical word problem can be found in literature. Word problem is any mathematics exercise where significant background information on the problem is presented as text rather than in mathematical notation [8,9]. On the similar note, Pfannenstiel, Bryant, Bryant, and Porterfield [9] defined word problem as combination of numbers and words in which students apply mathematics instruction in the context of problem-solving.

Conversely, Lai [10] defined word problem as problem designed to help students apply mathematics concepts to real-life situations. As word problems involve a narrative of some sort, they are occasionally also referred to as story problem and may vary in the amount of language used in the question.

The definitions bring in an argument whether mathematical word problems should be regarded as problems when attempted by learners or should be regarded as exercise. Mathematical problem to one learner might be an exercise to other. Stigler and Hiebert [11] indicated that depending on the experience and mathematical knowledge of individual learners, the same problem may represent challenges for each individual learner.

To optimize the ability in solving word problems, the knowledge of factors affecting students' ability to solve word problems is needed. Several factors: reading skills, language proficiency, and contextual understanding affect students' ability to solve word problems can be found in the literature.

Current interest in children’s mathematics skills has led to research into association between mathematical performance and reading skills. Vilenius-Tuohimaa, Aunola, and Nurmi [12] have conducted a study to investigate the association between mathematical word problem performance and reading skills. Their results showed that performance in mathematical word problems was strongly related to performance in reading comprehension. The research suggested that both reading and mathematics skills required overall reasoning abilities. The association between reading and mathematics ability has also been researched internationally. Lerkkanen, Rasku-Puttonen, Aunola, and Nurmi [13] conducted a study on mathematics and reading comprehension and the results showed that mathematics and reading comprehension was highly associated with each other. Nurjanah [14] revealed Students face problem related to vocabulary. These problems are related to poor habit of reading and less interesting reading comprehension course they have in the classroom. Conversely, Auzar [15] in one of the studies conducted to see the relationships of reading comprehension ability with the ability to understand the questions of mathematical word problems with 40

elementary students using a reading comprehension test, the results indicated that there were no strong relationships between reading comprehension with the ability to understand questions of mathematical word problems.

The studies reviewed mostly suggests that reading skills have effect on students' ability to solve word problems. Particularly, paying attention to semantic-linguistic features of word problems is relevant to help students improve their word problem-solving success. However, there is limited evidence to support whether a child genuinely interested in reading have positive correlation with a successful word problem-solving.

Standardized mathematics tests consist primarily of word problems that students must interpret before they can compute answers [16]. Despite the prevalence, many learners have difficulty solving word problems due to lack of comprehending word problems that come from the semantic structure of the problem and its language consistency with the required operations [17].

Language plays an important role in understanding word problem in mathematics. Familiarity or lack of it may determine the success or failure in understanding and working out word problems. There is large amount of language that students must attend to understand and solve word problems [17]. This makes solving mathematical word problem, even more, challenging for Bhutanese students where English is only the medium of instruction. It was shown in the study conducted where English is only their medium of instruction that students found word problems more challenging than non-verbal computations presumably due to the language component. It seemed that when problems were in their first language they understood and recalled them better as well as solved them using the correct operations [18]. Thus, teaching mathematical word problems in English language seems challenging for Bhutanese students.

The language that is used in mathematical word problems is different from a students' everyday language [19]. It was also declared by National Council of Teachers of Mathematics (NCTM) [20] that there is sometimes mismatch between ordinary English language and mathematical language, and students need help to bridge between their usage of language within and outside the mathematics classroom. Many ordinary English words are used in mathematical English with different language.

Additionally, Barb and Beal [21] pointed out, word problems written in complex language is rated as mathematically more difficult to solve than the same problems written in simpler language. Individuals who are not fluent in English may perform more poorly than their peers in other subjects that are not directly related to the language [22]. This brings the issue of language as a barrier to mathematics word problem solving for English as second language (ESL) students. Children's achievement in mathematics is connected to long-term outcomes in both mathematics and literacy [23]. Teachers' mathematics language has been found to predict children's mathematics outcomes [24] but there are only a few empirical studies that have examined teachers' mathematics language.

Students are expected to pay attention to their mathematics competence without neglecting their ability to make meaning and understanding written information given in the word problems [25]. The focus of school mathematics should help students make connections between mathematics and real-life situations [26]. Using students' names, events in their lives, and the mathematics skills being taught in word problems increases attention and lessens language-based problems [27].

Students who failed to correctly answer word problems were mostly the ones who did not pay attention to its context, but directly did the mathematical operation that they considered to be appropriate [28]. It was noticed that familiar context enhances word problems solving by increasing the meaningfulness of contexts [29]. However, the majority of students were unable to understand core concepts and apply knowledge to real-life situations, across grades and subjects, indicating a major gap in the levels of understanding [4].

The above mentioned gap in the levels of understanding the core concepts provides the importance of contextual understanding to solve word problems, however, the previous studies did not consider that students bring to classrooms a different learning experiences which will affect their interpretations of the

context. For example, a student who is not familiar with American sports may not understand the problem about football scores or baseball averages.

3 Materials and Methods

The study employed a qualitative research approach to gain insight into the factors affecting students' ability in solving mathematical word problems. The process of research involves emerging questions and procedures, data typically collected in the participant's setting, data analysis inductively building from particular to general themes, and the researcher making interpretations of the meaning of the data [30].

3.1 Research design

This research has followed a case study research design. In particular, this study was a single embedded case study as formulated by Yin [31]. It is a case of secondary school. However, this case study, it involved more than one unit of analysis. These units of analysis included the cases of students from classes 7 to 12 and the mathematics teachers of this school. It studied the word problem-solving ability of different class level students and the views of the mathematics teachers teaching in different classes.

3.2 Research site

This study was conducted at Punakha Central School, located in Western Bhutan. It is a typical whole-day school with 37 teachers and 859 students. The school has 19 classes from classes 7 to 12 with 7 mathematics teachers. The research site was selected based on the convenience of the researcher as the researcher approached the eligible site and the participants.

3.3 Participants

Participants for the study included students from all the class levels of the school and mathematics teachers involved in teaching these classes. The researcher used the purposive sampling technique [32] to recruit four students and four teachers. As the name purposive sampling suggests, the sample was chosen for a specific purpose that satisfied the researcher's needs to undertake the type of the study. Those four students were chosen one from class 7 and 8; one from class 9 and 10; one from class 11 arts and one from class 12 science. Teacher participants were the teachers who taught classes 7 to 12 mathematics.

3.4 Data collection tools

The primary source of data was collected through the use of a one-on-one semi-structured interview with students and teachers ranged in the length of 25 to 30 minutes. Each interview was audio-taped and transcribed verbatim to facilitate subsequent data analysis. Supporting data were collected through classroom observations in which the researcher acted as a non-participant observer [33] and document analysis of mathematics textbooks. Direct classroom observation was carried out through descriptive note-taking in a semi-structured way using prior questions. Document analysis of mathematics textbooks of classes 7 to 12 was used to get information on the use of the context of the word problems. The document analysis helped to collect information on whether mathematics textbooks have word problem questions in the Bhutanese context with the contextual language or not. A checklist was designed unit wise to check the use of the word problem questions in Bhutanese context, contextual language, and abstract language. This was done to validate the information which was done through other tools of data collections.

3.5 Data collection procedure

This study was approved by Samtse College of Education. At the school level, before visiting a school, prior permission was obtained from the Dzongkhag Education officer (DEO) and the principal of the concerned school. The researcher obtained written approval from DEO and the school principal to collect data. Before

the conduct of the interviews and the classroom observations, the researcher briefed participants on the purpose of the research and their right to withdraw from the research if they have any problem. The researcher distributed informed and voluntary consent form and participation information sheet to only those individuals who were willing to participate. The researcher conducted student participants' interview after the class to not disturb their regular classes and conducted teacher participants' interview during their free periods. Simultaneously, a researcher observed the teacher participants' class whenever they taught word problems. All the data collected through interviews and classroom observations were kept confidential.

3.6 Data analysis procedure

Thematic analysis was adopted (Fig. 1) to identify the factors affecting students' ability to solve word problems. Thematic analysis is a method for identifying, analyzing, and reporting patterns within data. Thematic analysis is also a form of "inductive analysis"; through inductive analysis 'findings emerge out of data, through the analyst's interactions with the data' [34]. In qualitative analysis, themes will emerge from the data rather than being pre-specified: 'themes are concepts indicated by the data [35].

The data analysis process involved several steps as described in Creswell's [30] data analysis in qualitative research. Firstly, data were organized and prepared for analysis. It involved transcribing interviews, typing the classroom observations, studying mathematics textbooks, and sorting and arranging the data into different types depending on the source of information. After gathering the information from the data, then started coding all of the data by writing a word representing a category in the transcripts and classroom observations. The researcher developed a codebook to provide definitions for codes and to maximize coherence among codes. The interviews codebook and classroom observations codebook provided a list of codes and a brief definition of it. Then used the coding process to generate a description of themes for analysis. Similar codes were grouped to generate the themes. Three themes were generated from the coding process. These themes appeared as major findings in this study. Finally, the findings from the three tools were triangulated and therefore it validated the data.

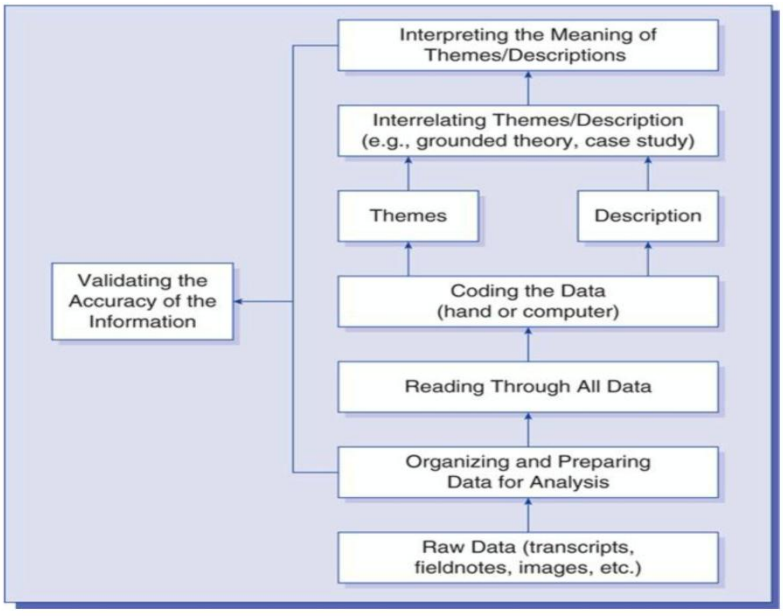

Fig. 1. Data analysis in qualitative research [30]

4 Results and Discussion

4.1 Results

The data collected through semi-structured interview, classroom observations and document analysis are analysed and triangulated to validate the findings. In doing so, certain parts of interview transcriptions of teachers and students and classroom observations are directly coded using codes such as Mt_1, Mt_2, Ft_1, Ft_2 to refer to each of the male and female teacher-interviewees, Ms_1, Ms_2, Fs_1, Fs_2 to refer to each of the male and female students and C_1, C_2, C_3, C_4, $C_{5,\ 6}$ to refer to each of the classroom observations.

4.1.1 Language proficiency

The Understanding of the question is a crucial aspect of word problem-solving. The students need to have an adequate level of language proficiency to understand and solve word problems. Therefore, the proficiency of language in solving word problems is inevitable for students as well as for the teachers. However, because of the long sentences and much information involved, students get confused about the objective of the problem. They are either not able to get the meaning in the problem, or they misunderstand the meaning. Students often misunderstand the problem as they lack adequate language proficiency. FS_2 pointed out, “As I don’t understand the language in the question, understanding the problem takes time…”. The teacher participants also said that the understanding of mathematical keywords or terminologies and the choice of the right operations become easy if they are competent in the language. FT_2 remarked:

It is important for teachers, as well as students, need to have good language to solve word problems. Because when teachers are not able to explain, students find it difficult to understand, and ultimately they are not able to come up with the right operations.

Also, FT_1 said, "I believe that if a teacher can explain it appropriately, I think almost 50% of the students will understand when explained with the single explanation". It was observed that besides English, teachers use other languages to explain mathematical word problems to the students. In the classroom observations in C_2 and C_3, it was found that teachers used English as the medium of instruction to teach word problems to the whole class but when they explained and monitored the students, they were seen using national language (Dzongkha). Similarly, students used Dzongkha while seeking clarification on their doubts and during group discussions. MT_1 shared, “Through student’s facial expression I can feel that they understand more when I explain word problems in Dzongkha”.

4.1.2 Reading skills

Poor reading habits can impede students' ability in solving word problems. Students face difficulty in solving word problems because they have limited vocabulary as they have read a limited number of books. MS_1 said:

The number of books I read is limited. Due to poor reading habits, I face difficulty in solving word problem questions. I believe if we read more books it will help us in solving word problems more efficiently.

Reading the word problem questions repeatedly can help the students understand better. It was also found that to solve the word problems, students have to read the word problem questions repeatedly to come up with the final solution. To formulate the equation and to choose the right operations, they have to read the word problem questions repeatedly, especially when they are solving multi-step procedures. The students said that they read the word problem questions maximum of three times to get the final solution. FS_1 said, “I usually read word problem questions three times because if we read one or two times we don’t get the right idea”. Correspondingly, the classroom observations showed that the teachers read and explained the word problems several times to make the final solution.

4.1.3 Contextual understanding

The interviews, classroom observations, and the analysis of mathematics textbooks revealed that context is important for the comprehension and solving of mathematical word problems. All the four teacher

participants regarded the importance of relating word problems to the real-life experiences. FT_1 said, "Mathematical word problems are important because it can relate the classroom teaching with the life experiences". Further, FT_2 and MT_2 maintained similar assertions:

There are some topics that I try to relate to students' personal life. For example, to teach class eight commercial mathematics, I give an example relating to our life. To teach simple interest, relate people availing loan from the bank and repaying with interest (FT_2).

Simply learning the numbers and figures do not help to solve word problems. If you are an engineer and you know all the calculus theory but don't know where to apply it, it makes no use of doing engineering (MT_2).

Teacher participants said that students who have had personal experience with the situations described in the word problems that they are more successful in understanding and solving them. MT_2 said:

As per my experience, I believe students are interested in the word problems are related to their life. They show less interest if word problems are abstract, be it in mathematics or in other subjects. Therefore, I think relating to real life situation brings more interest in students in solving word problems.

The data revealed that students have a preference for word problems associated with their everyday life. The mathematics textbooks from classes 7 to 10 have several word problems in the Bhutanese context that are explained in contextual language.

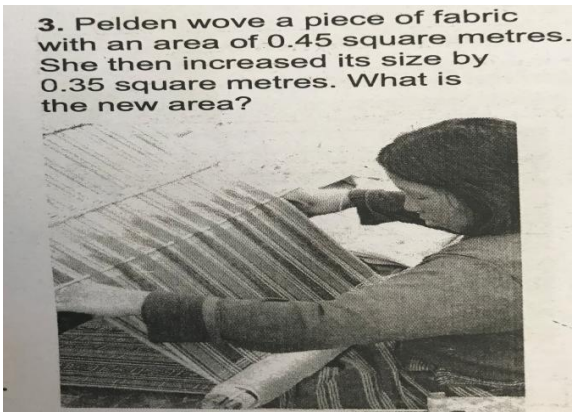

Fig. 2. Class 7 textbook used word problem in Bhutanese context [36]

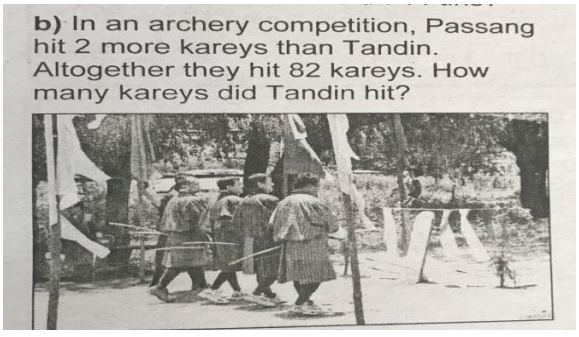

Fig. 3. Class 8 textbook used word problem in Bhutanese context [37]

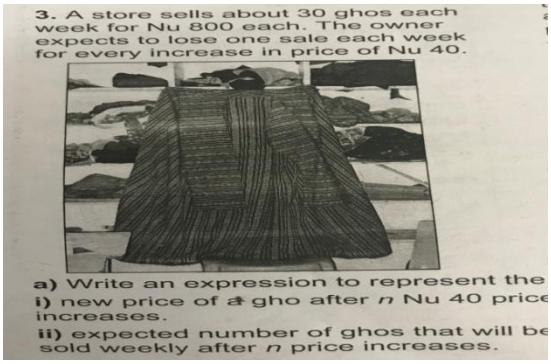

Fig. 4. Class 9 textbook used word problem in Bhutanese context [38]

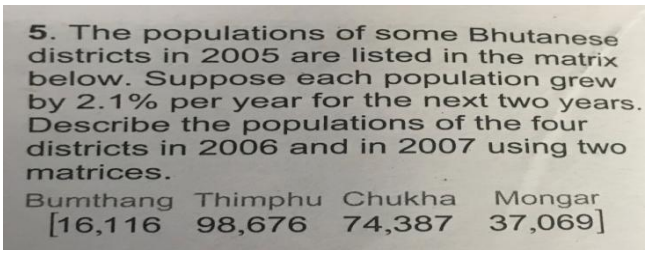

Fig. 5. Class 10 textbook used word problem in Bhutanese context [39]

However, the word problems of class 11 and 12 textbooks do not have contextual word problems instead the majority of the problems are in a less familiar language.

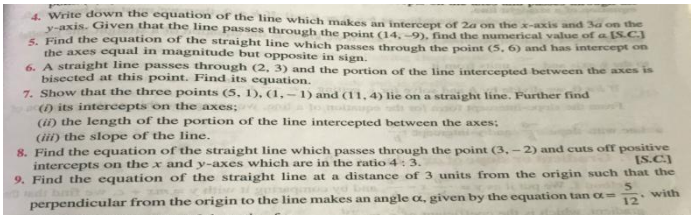

Fig. 2. Class 11 textbook used less familiar word problem language [40]

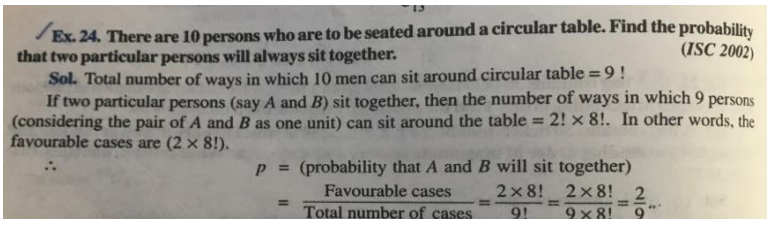

Fig. 3. Class 12 textbook used less familiar word problem language [41]

Classroom observations revealed that teachers teaching classes 7 to 10 relate the word problems with the real-world experiences and personal life experiences of the students. For instance, the concepts like volume, capacity, probability, and speed were related to the real-world experiences of the students. However, class 11 and 12 teachers were seen using abstract language without relating with the real-world experiences. They taught derivative, ellipse, and homogenous equation concepts without relating with the real-world experiences.

4.2 Discussion

The literature showed that individuals who are not fluent in English may perform more poorly than their peers in other subjects that are not directly related to the language [22]. Similarly, the findings of this study revealed that students' ability to understand the language in mathematical word problems greatly influences their proficiency at solving word problems. One possible reason for not understanding the mathematical language could be due to a mismatch between mathematical language and English language. For example, *function* in ordinary English means an activity that is natural to or the purpose of a person or a thing. However, *function* in mathematics means a relation or expression involving one or more variables, the *function* $(bx + c)$.

In addition, this study revealed that it is not only the students' proficiency in the language in solving word problems but also teachers' language that affects successful solving of word problems. The findings of this study are supported by Klibanoff et al.'s [24] study which found teachers' mathematics language to predict children's word problem-solving outcomes. There are only a few empirical studies that examined teachers' mathematics language in the literature. However, this study concluded that the language proficiency of students as well as teachers' can affect students' ability to solve mathematical word problems. It was clear that without the good English language of teachers, students themselves cannot successfully solve the word problems.

There is also an interplay between the mathematical word problem-solving skills and the reading comprehension. It is revealed that reading the word problem questions repeatedly can help the students understand better. Overall, the findings of this study are also consistent with the previous studies [12, 13, 16]. These researchers found that reading skills affect students' ability to solve word problems. Moreover, they suggested that students should read and re-read the problem to ascertain that they have responded correctly to the question.

The study also regarded the importance of relating word problems with the familiar context of the students. Literature pointed out that familiar context enhances word problem solving by increasing the meaningfulness of contexts [29]. The findings of this study revealed that students are more interested in word problems when the word problems are personalized and given in a familiar context rather than word problems that are taken verbatim from a mathematics textbook. This is evident from the literature that the majority of students are unable to understand core concepts and apply knowledge to real-life situations, across grades and subjects, indicating a major gap in the levels of understanding [4]. The possible explanation for the prevalence of such gaps could be because the word problems are not in the Bhutanese context with contextual language.

5 Conclusion

The increased presence of word problems on the Bhutanese mathematics curriculum was the impetus for this study and thus this study investigated what secondary teachers and students reported on the causes of difficulties students face when solving mathematical word problems. There are three factors for these challenges: language proficiency, reading skills, and contextual understanding. Language proficiency plays an important role in solving mathematical word problems. In fact, understanding the mathematics language provides access to the process of word problem-solving skills. Much of the attention focuses on students' ability to communicate in national language (Dzongkha). However, the teachers language in helping students solve mathematical word problems in the classroom was central. The teachers own use of language in the classroom serves as an important example of effective communication while solving word problems. This study implies that students' difficulties in solving mathematical word problems might occur at any classes. In fact, it might be caused by a deficiency in any of the skills either independently or cumulatively. Therefore this study revealed the significant role reading plays in teachers' and students' perspectives of students' difficulties in solving mathematical word problems. Owing to the importance of reading skills in solving mathematical word problems, researcher recommends the Ministry of Education (MoE) to place more importance on reading activities in the school. As a result, students could improve their reading habits

with improved vocabulary to enhance their language proficiency; which is inevitable for students**,** as well as teachers in solving mathematical word problems. However, the findings of this study may not be generalized as the study as some limitations. If this study involved more participants at different secondary levels, it would have been easier to generalize the results for a larger group. The study was conducted only in one school and therefore, the findings may not represent the case for other schools in the country.

Consent and Ethical Approval

The ethical issue in this study is taken into an account by the researcher. Prior to the collection of data, written approval was obtained from the concerned authority. Also, consent letters were duly signed by all the participants before completing interview and classroom observations.

Competing Interests

Author has declared that no competing interests exist.

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