Promoting Sustainable Development in School Classrooms: Using Reciprocal Teaching in Mathematics Education

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Abstract **– Many elementary students face difficulties in solving word-based, mathematical problems. This study explores using the reciprocal teaching instructional strategy for word-based, mathematical problems at the elementary level. We used a quasi-experimental research design for this study to address the reciprocal teaching environment design, implementation, and evaluation at elementary level mathematics education. Two sixth grade model classes, A & B, of a public secondary school from the district of Okara, Punjab, Pakistan, were selected for this study. Reciprocal teaching for mathematics appears to be an essential strategy for nurturing a more in-depth understanding of the text of mathematical word problems at the elementary level. This instructional approach could enhance an extraordinary level of skill in critical thinking, reasoning, and understanding.**

Keywords **– Mathematics; word-based problems; reciprocal teaching; elementary level; reflections.**

1. Introduction

The United Nations Sustainable Development Goals (UN SDG) ensure inclusive, equitable, quality education. They also provide lifelong learning plans for all. Sustainable development emphasizes lifelong, equal learning opportunities and encourages changes in knowledge, skills, values, and attitudes to build a more sustainable, fair, and high-quality education for everyone. Education for sustainable development is the result of human beings' reflection on their behavior.

Through the establishment of Goal 4, an independent education goal, and other, specific related indicators, the United Nations Sustainable Development Goals 2030 Agenda recognizes that education is essential to the successful realization of sustainable development [1].

It is widely recognized that mathematics serves as a gateway in education; students with strong mathematical skills are more likely to have better outcomes and end up with better educational paths than those who performed low in mathematics [2]. Our focus is on the sustainable development of students in elementary mathematics education.

Textbooks on mathematics and standardized exams include a growing array of word-based problems that students need to solve [3]. Teachers tend to teach to the textbook. However, a textbook usually presents systematic math content. Therefore, teaching methods and mathematics may not be aligned. Besides the content in textbooks, new teaching strategies are needed to improve students' understanding of math.

When teachers come across students trying to obtain knowledge in their specific fields and academic accomplishments, they strive hard to incorporate various strategies, introduce new solutions, and attempt to fill the learning holes, such as deficiencies in the interpretation and comprehension of a word problem statement. This can be even more significant in science topics because word problems require further focus and discussion to clarify the definition. Numerical questions include the capacity to learn and consider how to react [4].

Some students understand the purpose of mathematical word problems and are considered effective math word problem solvers. They show this through their aptitude to describe the question in their

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expressions. Nonetheless, many students do not have this ability [5].

Factors such as irrelevant numerical and linguistic details, mathematical language, vocabulary complexity, the variety of ideas raised, and the linguistic difficulty of the word problem can render it exceptionally difficult to understand [6].

A teacher does not only provide knowledge to students, but also needs to learn how to guide student thinking, such as asking the right question, predicting, and researching ideas about math problems. Therefore, reciprocal teaching can be a successful alternative to traditional teaching methods [7].

Teachers observe during their teaching practices that many students face difficulty in solving word-based, mathematical problems; however, these learners show a good understanding and ability to answer numerical questions, as well as the right choice of adequate mathematical procedures.

Why Reciprocal Teaching?

Below are the three core goals of reciprocal teaching:

1. It is a structure for the explicit teaching and implementation of four basic strategies that promote approaches for creating self-monitoring essential to successful understanding.
2. It uses a well-established framework for social interaction.
3. It is a platform for collaborative action [8].

Reciprocal Teaching

Reciprocal Teaching is an evidence-based, dialogical instructional approach that supports a collaborative process of teaching-learning between teachers and students to jointly construct the meaning of the text. Communication takes place between teachers and students regarding the fragments of the content. Summarizing, questioning, clarifying, and predicting (SQCP) are the strategies used to construct the communication between teachers and students. This exercise plays a vital role in understanding the text. First, the teacher starts the process and gradually hands over the command to the student [9].

Primary Stages of Reciprocal Teaching

Reciprocal teaching is a constant practice through this procedure; learners acquire the skill to recognize the manuscript, question, and purpose, and reproduce them upon his/her own questions. The educator guides the pupils at the start, leading the dialogues, but progressively transfers the process to the pupils letting them have control over their own understanding and learning (Fig 1).

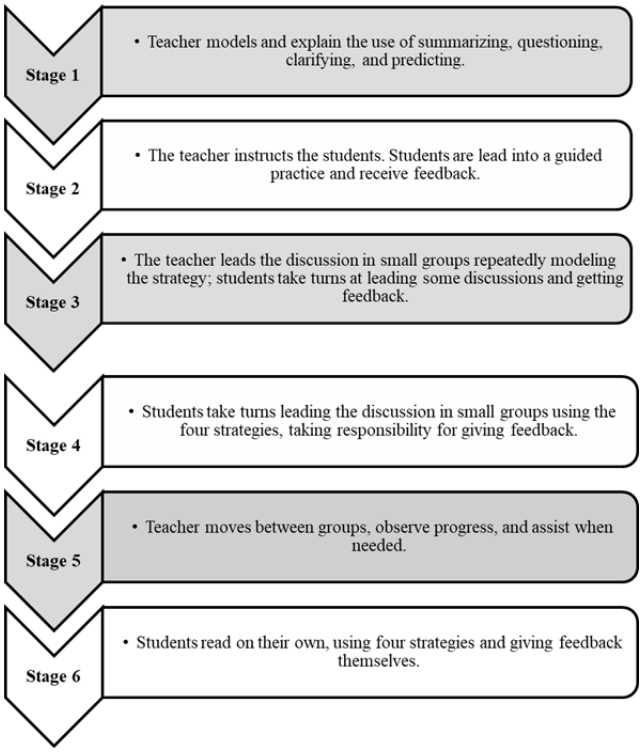

Figure 1. Stages for Reciprocal Teaching [10]

To get a clear understanding of the knowledge at any stage or level of instruction, the learner needs to read supplementary information. To achieve the depth of complex concepts of word problems in mathematics, students need to clearly comprehend the meaning of the text.

If students use SQCP during their learning, they can find any gaps and reach their solutions because they have control of the learning practice and are capable of examining and revealing facts from the reading content. The interface with the instructor and other learners eradicates mistakes in learning. This practice can explain the significance of different terms and problematic impressions. The SQCP process enhances the ability of students to understand the concept of questions and absorb the vocabulary of new and challenging words. Through this strategy, the learner connects him/herself to the whole idea of the text. This entire concept of sequential learning phases has been used at different levels of education to increase the ability of students to understand and comprehend the knowledge [10].

Four key strategies (Table1) are used to improve learners' reading skills during the learning process, and this process is called reciprocal teaching.

Table 1. Key strategies to improve learners' reading skills

Strategies	Tasks Involved
Predicting	▪ Students must accelerate what occurs next. ▪ This is based on previous information. ▪ Motivation to continue reading. ▪ Helps to determine their original guess was accurate. ▪ Boosts learners to reflect onward.
Clarifying	▪ Students are stimulated to find areas of problem, e.g., unfamiliar terms, novel, and challenging notions. ▪ To fix the areas of scarcity and then re-read the text to reestablish sense. ▪ Particularly suitable for students who face difficulty in understanding the text flow.
Questioning	▪ Data, concepts, and ideas that are essential and relevant enough to solve the problem further. ▪ Self-tests for the reader. ▪ To create why and how questions to understand a passage leading to further questions and discussion in the group. ▪ Reinforces summarizing strategies.
Summarizing	▪ Students need to identify and incorporate critical knowledge that appears in the text. ▪ It may be in an expression, paragraph, or the whole text.

[10–12]

Mathematical Literacy

Understanding the text is crucial to reaching and then addressing a mathematical problem [11]. Mathematical literacy depends mostly on academic vocabulary [13]. Reading of mathematical texts and solving both complicated and straightforward word problems are standard in elementary education. In contrast, teachers' disappointment in students' skills in assigned work is equally common. Mathematical literacy is defined as the process of teaching, learning, and using mathematics' numeracy; a comprehensive set of developed behaviors and dispositions are essential for active involvement in society [12].

Mathematical Word-based Problems

Mathematics and multi-subject teachers are mostly concerned about their students' poor performance during written mathematical problems, and they argue that their students are not adept at understanding mathematical phrases. Teachers identified that the organization of educational words is critical for developing mathematical literacy [13].

It is a common observation by many teachers that many of their students do not even understand the *mathematical* meaning of simple words, and it happens abundantly with non-native English speakers. Understanding the text is vital to accessing and solving mathematical problems [7].

Generally, students at the elementary level face difficulties in interpreting the mathematical text in the following four areas [8], [14]:

1. Reading the problem:
   - Non-native English-speaking students face difficulties in reading the question.
   - Students have to learn to read and understand the text to be able to take further mathematical action.
2. The difference between scenario, information, and question:
   - Students need to differentiate among these three parts of word problems, and then they will be able to solve them.
3. Order of information:
   - Most students get confused about the information given in the question; they find it challenging to recognize the mathematical procedures (e.g., write the sentence as an equation 371 equals y decreased by 12: 371 = y − 12).
4. Confusion about prepositions used:
   - Prepositions in questions may confuse students (e.g., what number, divided by 16 is 4, compared to 16 is divided by 4).

One critical disposition that learners need is code-breaking [14] to gain a better understanding of mathematical word problems. Gradually different teaching strategies have been exercised in schools by the government. One of them is reciprocal teaching.

Mathematics and Reciprocal Teaching

The reciprocal teaching strategy is based on the model presented by [9] and later [11] modified the model with the addition of ''recording'' as the fifth step (Table 2).

Research on the use of reciprocal teaching in science subjects

Riyanningish studied the effects of reciprocal teaching in chemistry and concluded that reciprocal instruction provides impressive outcomes for students in chemistry with multiple lessons. In the studied group, the degree of comprehension was improved by using a reciprocal teaching strategy.

Reciprocal teaching is ideal, but not only for the comprehension of English, the strategy may also be integrated into scientific topics to teach various science subjects of Oludipe in 2014 cited by [4].

Reciprocal instruction is also beneficial for the reading and comprehension capacities of biological

texts. In biology, sometimes, the context of a text contains two or three interpretations that require logical clarification. This kind of scenario can be overcome using the reciprocal technique to acquire the real concept in the text [15].

Table2. Five dimensions of reciprocal teaching for mathematics [16], [17]

Strategies	Tasks Involved
Prediction	▪ Type of questions. ▪ Type of mathematical operations. ▪ What their answer might look like. ▪ Stressing the use of previous information. ▪ The structure of the writing, captions, content, and figures.
Clarification	▪ List three groups of information. ▪ Words of which they are unaware. ▪ All the evidence they identify. ▪ Thinking and successfully solving the problem. ▪ Working as part of a group. ▪ Clarifying all areas of deficit. ▪ Reading the text again to recover the connotation.
Solving	▪ Learners solve the problem. ▪ Several problem-solving options. ▪ This authorizes the learners to advance an answer which is related to them. ▪ Students are required to signify their task and answer using pictography.
Summarizing	▪ Self-reflection. ▪ How they contributed to the group assignment. ▪ Focus on the strategies they have chosen. ▪ How they would refine the process if presented with a similar problem. ▪ Justification of their answer. ▪ Mathematical solutions offered by each group should be discussed.
Recording	▪ Participants are expected to maintain a written record of the completed element at each stage. ▪ It integrates reading and writing, and reinforces the importance of both. ▪ It leads to improved comprehension. ▪ It provides the necessary corrective feedback to help students.

Zachary (2009), cited by [4], noticed an improvement in the performance of academically weak students with the use of the reciprocal teaching strategy. The experience of these students improved relative to those students who were already used to the standard methods. The intervention led to students improving their understanding and enhancing their confidence, which led them to be more result-oriented in the subject of biology.

After following a three-month plan to use reciprocal teaching, the students' attitude to solving mathematics-related problems was strengthened for grade seven [11]. A study was conducted to investigate the effect of reciprocal teaching on students' comprehension abilities for mathematics word problems. The research findings showed that success in mathematical word problems and the interpretation of the text is strongly linked. The basic reading abilities were improved with the success of word problems [18].

Teachers observed during their teaching practices that several students faced difficulty in solving word-based mathematical problems. Nevertheless, these learners showed a good understanding and ability to answer numerical questions, as well as the choice of proper procedures and methods. It is common knowledge that most students have a phobia of mathematics. Many researchers found the main reason for low math performance is caused by mathematical literacy deficiency [13], [14], [16].

This deficiency remains until students get command over the comprehension of mathematical word problems. So it is indispensable to teach students by using a good, productive strategy. Reciprocal teaching is one of the successful instructional and designed tactics that accelerates pupil understanding [12]. This strategy also enhances the knowledge and confidence of students' during difficult tasks and reading.

Pakistan's schools, especially those run by the government, are training students with alarmingly low levels of learning in key disciplines such as math and science. This leads to a major and deep-rooted challenge to the country's economic growth. The average score of the participants was below 30%, reflecting the overall low output of all schools that participated from Pakistan in mathematics assessments based on the 2011 TIMSS evaluation system [19].

Hence, it is a challenge for educators to encourage and prepare all students to reach a high level of word problem-solving. Given the limited research on this topic in Pakistani literature, this study attempted to present procedures for designing, applying, and evaluating reciprocal teaching to assist the development of comprehension of mathematical word problems in elementary schools in Pakistan. The below three research questions guided the research.

Research Questions

RQ 1: How can the environment for reciprocal teaching in mathematics at the elementary level be designed?

RQ 2: How can reciprocal teaching in mathematics education be implemented at the elementary level?

RQ 3: How can the reciprocal teaching method in mathematics education at the elementary level be evaluated?

2. Methodology

Context and Mathematics Curriculum

This study was conducted in one model public secondary school at District Okara, Punjab, Pakistan. Secondary schools in the Punjab province generally consist of three-level classes, i.e., primary, elementary, and secondary. Each class is further divided into more than one section, e.g., Sixth Iqbal. Sixth Quai-e-Azam, etc. However, this study deals only with the sixth class of the elementary level of the selected school.

The sixth class is one of the essential and terminal classes. The students appear in the board examination for their fifth class (primary level), and if they pass, they move to the sixth class, which is the first step of elementary level in Pakistan. This then leads to the secondary level. The division of classes depends on the number of students. Public secondary schools are crowded, which means that forty to sixty students could be present in a class. However, in a model school, the number could be less with a maximum of up to forty students in a section.

The sixth-grade mathematics book was used for this study. This book, consisting of thirteen chapters, is distributed by the Punjab government for free to public school students. Chapter five, 'simplification,' and chapter six, 'ratio & proportion', were taught during this study. These chapters were included in their first term syllabi, so it was convenient for teachers to teach them, and both chapters have word-based mathematical problems (for more details, visit https://elearn.gov.pk).

Research Design

The Posttest-only quasi-experimental research design [4] and continuous observation were used for the present study. Two groups of students were selected; one as an experimental group and the other as the control group. The experimental group received an intervention that is the "Reciprocal Teaching Approach." The control group received the traditional lecture method. Both groups were observed by their math teachers during eight weeks of the experiment and also given the posttest (O1, O2) after the treatment (X1, X2).

Two math subject teachers were selected and discussed all the study settings in detail well before the intervention. Both of them were well trained in mathematics education and had attended different levels of teaching training, including reciprocal teaching.

Participants

A total of seventy (70) students participated in this study. Two same performance level classes of sixth grade (6^{th}) were selected. Each class consisted of 35 students. 'Class A' students received the intervention two times a week for thirty-five minutes each time for eight weeks, and 'Class B' used the traditional lecture method. The same syllabi were provided to both classes. Class A was divided into seven groups of students, and each group consisted of a maximum of five members. Teacher assistance and a variety of materials were accessible by all participants. Several observations were noted throughout the sessions.

Instruments

Three instruments were used for this study, the first lesson plan based on a reciprocal teaching model (see table 2) [9], [11]. An observation sheet (see appendix) adapted from [20] consisted of sixteen items, and the third a posttest (see appendix) to measure the students' word-based mathematics problem-solving ability.

Data Collection

A participation consent form was distributed to all 70 participants. They were all asked to indicate their willingness to participate in the study. The experimental group teacher planned all his lessons based on reciprocal teaching methods, and the control group teacher planned theirs based on the traditional teaching method. Both teachers were given printed, observational sheets and a notebook to record the observations. They observed throughout the study period and handed over all sheets and a brief report to the author one at the end of the study. Furthermore, at the end of the study, a posttest was conducted from the taught syllabi.

Data Analysis

A criterion (Table 4) was used to describe the students' word-based math problem-solving ability based on the posttest – the school officially uses this criterion for the grading to students, and the percentage was used to describe the difference between the two group's posttest scores. Furthermore, data from observations were analyzed through thematic analysis. Seven themes (Fig. 2) were generated from the observations.

3. Results

The following were the main findings of the present study. Here are the pre-treatment effects of the study-based on mid-term schools' results.

Table 3. Comparison of mid-term school's scores (Pretreatment)

Class	Group	N	Mean	SD
A	Experimental	35	37.9104	6.38761
B	Control	35	37.9011	6. 37213

SD: Standard Deviation

A comparison (Table 3) was made of two groups before treatment, and both groups' performance was equal in their first term school results. Hence, their selection and division for this study were appropriate.

A posttest was used to find the word-based math problem-solving abilities of both groups, and an observation sheet described earlier was used for continuous observation during this study. Based on the post-test results, the experimental group students' word-based mathematical problems solving abilities were better than the control group. We describe the posttest result first to give an overview of the study; however, we later discussed the findings from the observations.

Table 4. Posttest: Mathematical Word- Base problem-solving ability Score

Criteria		Experimental Group		Control Group	
Score Range	Level	Frequency	Percentage	Frequency	Percentage
$90 \leq X \leq 100$	Outstanding	03	8.57	01	2.86
$80 \leq X \leq 89$	Excellent	09	25.71	04	11.42
$79 \leq X \leq 70$	Very good	16	45.73	09	25.73
$60 \leq X \leq 69$	Good	03	8.57	15	42.86
$50 \leq X \leq 59$	Needs improvement	03	8.57	04	11.42
$40 \leq X \leq 49$	Unsatisfactory	01	2.85	02	5.71
$0 \leq X \leq 39$	Failed	0	0	0	0

Findings generated from the observations

Time efficiency

Class B completed their task more quickly than class A. More than five times, class B finished five questions in thirty-five minutes; conversely, class A took the full time of the period; however, they only solved two or three questions.

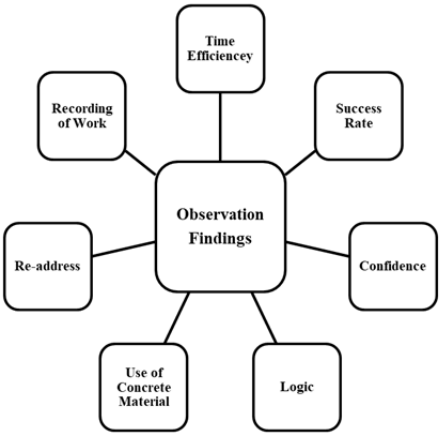

Figure 2. Themes generated from observations

Success rate

Students of both classes were confident about their solutions; however, after reviewing the solutions, only ten to twelve students of class B correctly solved questions. On the other hand, twenty to twenty-five students of class A solved questions with correct procedure and answers.

Confidence

Students of both classes were confident about their solutions; class B was so confident that most of them did not verify their answers. They did not ask for assistance for their work. However, class A's students asked for assistance at different times.

Logic

Most of the students in class A were able to answer the questions related to their work asked by the teacher. However, many students from class B did not answer appropriately about their mathematics work; an average of three to five students answered logically, although their work was ok.

Use of concrete materials

Class A was using concrete material, e.g., blocks and pictures, to solve their problems, and their answers were correct. On the other hand, students in class B did not use any proper plan, and many just casually handled the quantities in the problem. Only a few students asked for concrete materials, and their responses were better than those who did not use them. This exercise showed the usefulness of concrete materials to solve a problem. Class A frequently used concrete materials, so they had a more robust understanding and more effective results.

Re-address

Students in class A were continuously re-addressing the questions' statements three to four times before offering the solution. Class A had been provided with a proper procedure to attempt the question. However, class B did not use any specific process, so they just read the question and then answered it.

Recording of work

Class A was provided with a notebook to keep a record of all work under the four strategies, and students recorded according to instructions. Class B did not record minimal work; from their work, it was difficult to determine the ideas or solutions they had established.

4. Discussion

The present study explored using the reciprocal teaching instructional approach to mathematical word-problems at the elementary level in Pakistan. The study results not only show some characteristics of, and relationships between, reciprocal teaching and students' mathematical performance, but also provide new evidence on reciprocal teaching in a South Asian developing country context.

We chose the elementary level to observe the effect of reciprocal teaching. Researchers favor that we use reciprocal teaching in different subjects and content areas, as in this study, we used it in elementary mathematics education [4], [15].

This study used a reciprocal teaching strategy to teach the whole class rather than smaller groups; our results are supported by researchers in this regard [4], [21]. This research work shows a robust, positive association between planned teaching and performance. The schools need to improve their student's compression skills to achieve good results. This is in line with an earlier study that confirmed that planned teaching is effective when tutors perform effective tactic for students, mainly when this demonstration is thoughtful and clear [20].

This study evidenced that students given reciprocal teaching enhanced their comprehension level during the study period. The tactics implanted in reciprocal teaching signify the successful students' involvement while intermingling with text. They work to inspire self-regulation and self-monitoring and stimulate planned education; the same was confirmed by many researchers [18].

Furthermore, during reciprocal teaching, students were in collaborative learning as a group discussion, and an excellent communicative environment; these factors were beneficial for their learning process. Our findings are in-line with other researchers [22], [23]. During this study, we found improved mathematical performance, communication inside the group, thinking skill improvement, and a better understanding of the text. These findings are in line with previous researchers' findings. Students' dialogues were improved through reciprocal teaching. General thinking and knowledge of valuable information in text improved [9], [15].

Students learned new strategies and applied them in their learning during this study. Students can demonstrate knowledge of these strategies and use them [2], [24].

It was noted during this study that reciprocal teaching consumes more time than other strategies during different steps, e.g., teacher transfers the command to students, and a teacher explains the strategies, etc., so this is a disadvantage of reciprocal teaching. Our findings are in line with [3], [25].

These findings expand what is already known about reciprocal teaching. Reciprocal teaching is related to improving students' understanding and social skills. This study confirms that this type of strategy is time-consuming; however, these strategies are useful for students learning growth.

5. Conclusions

Reciprocal teaching in mathematics enhanced an extraordinary level of skill in critical thinking, reasoning, and understanding. The five stages (predicting, clarifying, solving, summarizing, and recording) of reciprocal teaching in mathematics boosted the students' thinking, communication, and leadership abilities. The use of concrete materials to visualize a solution is also one of the vital tools for success in mathematics learning. Reciprocal teaching for mathematics appears to be an essential strategy for nurturing a more in-depth understanding of the text of mathematical word problems at the elementary level. Students feel more relaxed and confident in posing questions and participating in productive and substantive conversations because they learn to have, and lead, discussions.

To promote the development of mathematics education in schools, the first step is to change teachers' concepts. Concepts are the forerunners of action. Reciprocal teaching is, in fact, an essential way of training in mathematics. This research indicates that reciprocal teaching allows students to become autonomous because they apply these strategies themselves during the teaching-learning process.

Limitations & Future Directions

First, the sample consisted of only boys because, in study settings, no co-education public secondary

school was available, so in the future, this type of study could be done in an environment where all genders can participate. Second, the time frame, this study planned only for eight weeks; however, it is recommended that the study should start at the beginning of the academic year to get more sophisticated results.

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Appendix

Post-test

Name & Roll #: Total Marks 100

Subject: Mathematics Class 6th Section: Time 2 hours 30 minutes

Note: Solve all questions.

Q 1: What are three points needed to concentrate while solving a word problem? (10 marks)

Q 2: Iram bought 3/4 kg tomatoes, 1/2 kg potatoes, 1/4 kg carrots and 2 kg apples from a market. How much weight of vegetables and fruits did she carry from the market? (10 marks)

Q 3: A showroom owner bought 30 kg mangoes for his workers. He gave 3/2 kg to each of 14 senior workers and every junior worker got 3/7 kg from the remaining mangoes. Find the total number of workers of the showroom. (10 marks)

Q 4: Salem's salary is Rs. 12000. He gave 1/12th of his salary as alms, half of the remaining for house expenditures and 2/5 th of the remaining as debt that was due upon him. What is the remaining salary with him? (10 marks)

Q 5: Shcraz purchased 24 notebooks at the rate of Rs. 12.45 per notebook, 48 lead pencils at the rate of Rs.3.25 per pencil and 25 ball point pens at the rate of Rs. 4.15 per pen. Find what remaining amount he has out of Rs. 1000. (10 marks)

Q 6: If 150 shirts can be stitched on 6 sewing machines in a day, how many machines are required to stitch 225 shirts in a day? (10 marks)

Q 7: 72 persons have enough food for 7 days. But after 1 day they decided to finish the food in 3 remaining days. For it they invited more persons. How many persons did they invite? (10 marks)

Q 8: The score of Inzmam-ul-Haq was 78 runs in a one day match, whereas the total score of the team 325 runs. Find the percentage of Inzmam's score. (10 marks)

Q 9: Naeem gave 25% of a profit to his partner. If the partner got Rs.4000, what remains with him? (10 marks)

Q 10: Baber is a paying guest in a house, where he shares all utility bills equally with the landlord. What amount will Baber pay if the electricity bill is Rs.1240.50, Sui gas bill is Rs.435.60 and water bill is Rs.278.90? (10 marks)

Observation Sheet

Date:

Class:

Total Students:

Present Students:

No	Observation Statement	Yes	No
1	The students are ready to learn		
2	The students pay attention to the teacher explanation		
3	The students respond to the teacher's questions		
4	The students ask about the unclear parts of the teacher explanation		
5	The students try to apply reciprocal method during class		
6	The teacher and the students are discussing the text		
7	The students make a prediction about the text		
8	The students are able to generate question from the text		
9	The students clarify the unclear parts from the text		
10	The students summarize the text		
11	The students are enthusiastically working in the group		
12	The students are active during the discussion		
13	The students are confident when they share their idea in the group		
14	The team leader leads the discussion		
15	The Students were recording their work		
16	The team leader helps all his/her members to understand the text		

Notes: