Study Note

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Impact of Model Drawing and Visualization to Solve Word Problem of Equation at Grade-8 in Nepal

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Abstract

This research aim is to know whether teaching word problems of mathematics to young learners through model drawing and visualizing is effective or not at basic school, especially for grade 8 students in Nepal. For this, 25 students were randomly selected as an experimental sample and pre-test consisting six-word problem administrated to the students to determine the baseline. The lesson structure of the experimental class was composed of Hogan & Forsten (2007)'s eight steps of model drawing approach guided through interpretation, visualization and mathematical equation. Finally, post-test consisting six-word problem administrated to the students to detect the effect. At last, through social validity survey students' opinions about model drawing and visualization were collected. The data was analyzed using parametric t-test. The result shows a significant difference between the mean achievement of students before and after treatment. The use of model drawing, visualization and its impact on student learning shows that this approach improves student's knowledge, comprehension and application ability to solve word problems of equation.

Keywords: model drawing, visualization, word problem, bar diagram, problem solving

1. Introduction

According to Curriculum Development Center[2], Nepal, the effectiveness of a curriculum relies on its implementation. The teaching method should be practical and effective in order to transfer the learning achievements set by the curriculum. Schools and classroom environment, as well as the activities conducted in classes are considered as the key elements for the successful implementation of the present-day formal school curriculum. The relations between school and community, teacher development and management, education materials and the evaluation system bring about great effects on the instructional approach. Similarly, instructional approaches are considerably significant from the angle of teaching and learning because a teacher has to play the role of a communicator, co-learner, facilitator, motivator and agent to make learners inquisitive in learning (CDC, 2007). Learning activities are conducted on the basis of textbooks designed in accordance with the curriculum developed at central government. The aspects such as grade teaching, multi grade teaching, subject teaching, community work and project work have not been given due importance. Teaching learning environment has

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[2] Curriculum Development Center is an organization under Ministry of Education, Science and Technology, Nepal.

happened to be more instruction-oriented than learning-oriented. Currently, teachers still follow the traditional approach. Therefore, the challenge of the day is to develop and implement curricula and curricular materials in good coordination with stakeholders so as to transform teaching into learning, establish collaborative learning, design child-centered instruction by using information and technology, learning through project work and group work (CDC, 2019)[3]. To improve students' learning, Nepal need to reforms of its educational system and teaching approaches. In Nepal, the basic education curriculum, 2020 it is most recent and updated one, where learning area of mathematics was divided into six main areas namely; Set, Arithmetic, Mensuration, Geometry, Algebra, and Statistics. As part of the new basic mathematics curriculum, the 'model drawing' and 'structure-problem solving' method were introduced as an innovative method to help students to solve word problems of mathematics (CDC, 2020). Actually, model drawing and visualization in teaching approaches that certainly help teachers in their teaching style and that also help to create better understanding in students so students can solve mathematical problems easily.

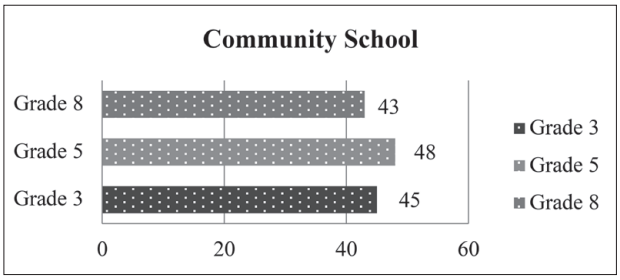

Figure 1. Achievement in Mathematics by Grades.
Source: Developed by authors based on MOE (2011, 2015).

Figure 1 shows that in national assessment of student's achievement report 2011 and 2015 conducted by Ministry of Education, the learning achievement of mathematics in grade 3, 5 & 8 were 45%, 48%, and 43% respectively. However, the national minimum standard is 60 percent so, the current score in mathematics was not sufficient and satisfactory.

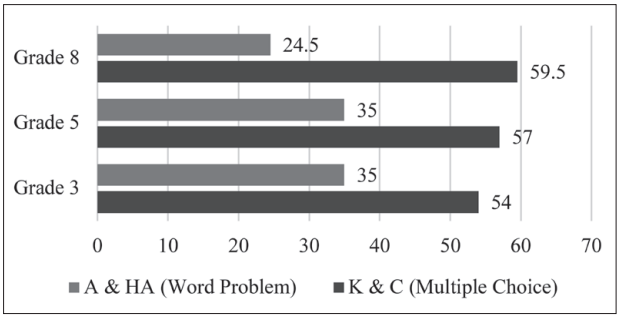

Figure 2. Achievement in Mathematics by Types of Question.
Source: Developed by authors based on MOE (2011, 2015).

Figure 2 shows that in national assessment of student's achievement report 2011 and 2015 conducted by Ministry of Education (MOE)[4], the learning achievement of mathematics in grade 3, 5 and 8 according to the question based on Knowledge and Comprehension (i.e., multiple-choice question) was better than the question based on Application and Higher Ability (i.e., word problem). Reasoning problems were considered as Higher Ability by MOE (2011).

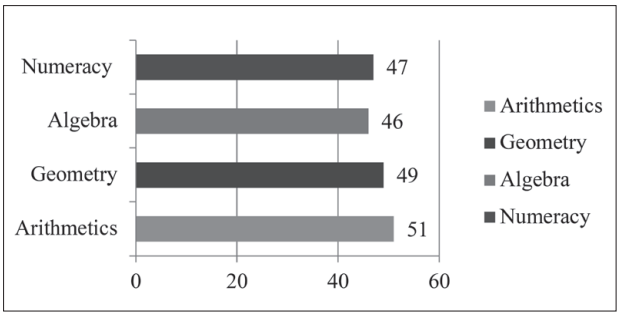

Figure 3. Achievement in various Content areas of Mathematics.
Source: Developed by authors based on MOE (2015).

Figure 3 indicates the learning achievements of grade five students were lowest in the content areas of Algebra (46%) and Numeracy (47%), the highest in Arithmetic's (51%), and in Geometry (49%). The achievement in Algebra was remarkably lower compared to Numeracy, Arithmetic and Geometry.

1.1. Statement of the problem

- Up to grade 8, achievement in mathematics was below minimum standard 60 percent and

[3] Some of the references of CDC are available on website and contents are in Nepali language.
[4] Ministry of Education (MOE) renamed as Ministry of Education, Science and Technology (MOEST) with the decision of Cabinet in 2018 AD.

student's achievement was very low, especially in algebra.

- Word problem has been challenging to understand and solve by the students in the area of Mathematics.
- Teacher were unable to use innovative teaching method such as visualization & drawing in order to develop application and higher ability. Still teachers are using traditional pedagogy of teaching.

2. History of model drawing and visualization

The only document that has a rather complete narrative of the 'model' method is the monograph entitled "The Singapore model method for learning mathematics" (SMOE 2009), It is reported in the monograph that to help students overcome difficulties they were having with word problems, Dr Kho and his team in 1983 innovated a method, the 'model' method. The monograph does not state any research or curricula that guided the innovation (Kaur, 2019). In 1983, the Singapore Ministry of Education (SMOE) officially introduced a heuristic involving diagram or model drawing known as the model method into the primary mathematics curriculum. The model method can be used as a tool for solving both arithmetic and algebraic word problems involving whole number, fraction, ratio, and percent (Kho, 1987). It was believed that if children were visualizing a simple arithmetic word problem or an algebraic word problem the structure underlying the problem would be made overt. Once children understood the structure of the problem, they were more likely to be able to solve it (Kho, 1987).

3. What is model drawing and visualization?

Model drawing is one of the most powerful teaching techniques that helps students to understand and solve word problems of mathematics easily. In this method word problems of mathematics are presented visually which helps students to understand the concept of the question. Basically, 'drawing models' requires us to draw boxes or rectangles to represent the numbers. It enables us to compare numbers, fractions, ratios and percentages easily. Most commonly, the model drawing is also known as bar modelling (Lim, 2017). This method is very useful up to grade 8 and also famous in Singapore, Third International Mathematics and Science Study (TIMSS, 2003). On the other hand, visualization refers to our ability to create pictures in our mind based on text we read or words we hear. This method is an ideal strategy to teach students who are having trouble reading (Arcavi, 2003). According to Miller (2004), teachers should follow the step by step plan to teach visualization.

Hogan & Forsten, (2007) indicates the model drawing, a powerful problem-solving tool that opens new pathways to learning mathematics for students at every skill level. It offers a new way to teach students, using visual models and logical thinking to build problem-solving skills. Model drawing is just what the name implies: drawing simple visual models to represents word problems. The drawing help students to see-literally-what word problems are all about. That is pretty amazing stuff. And it really works!

For students with mathematics difficulties, math word problem solving is especially challenging. National Council of Teachers of Mathematics (NCTM) indicates that math word problem solving must be a fundamental part of mathematics, and underscores the interdependence between problem solving and successful conceptualization of mathematics across content and grade levels (NCTM, 2000; Cai and Lester, 2010). However, math word problem solving continues to be a problem for many students. A report issued by the National Mathematics Advisory Panel US (NMAP) cited an example in which 45% of eighth-grade students were not able to solve a word problem that involved dividing fractions (NMAP, 2008). To examine the effects of a problem-solving strategy, bar model drawing, applied to the mathematical problem-solving skills of students with mathematics difficulties. The models do not depict actual objects from the word problem, but depict quantities and relationships between quantities (Ng & Lee, 2009). Representations similar to that of the 'model' method are also prevalent in other elementary school curricula. In Japan they are called tape diagrams and, in the US, "strip" diagrams (Murata, 2008).

3.1. Research Objectives and Questions

- To develop the lessons, applying the visualization

through model drawing approach for word problem of equation at the 8th grade.

- To boost application skills and academic performance of students to solve word problem of equation through the developed lessons based on visualization and model drawing approach.

For above two research objectives, the corresponding research questions were as follow:

- What kind of lessons (lesson plan and material) can be developed, applying visualization through model drawing approach for word problem of the equation at 8th grade?
- Can the developed lessons based on visualization through model drawing boost the application ability and academic performance of students to solve word problems of equations?

4. Methodology

In this study, one of the secondary schools in Nepal was randomly selected as a sample. There were six sections (A-F) in 8th grade at that school. For the study 25 students of section F were chosen randomly as an experimental class (EC). Pre-test, intervention lessons, and post-test were utilized to detect the effect of the study. After intervention lesson, social validity survey was used for students to know student's opinion about model drawing and visualization.

4.1. Pre-test

Pre-test was conducted to measure base line of students before face to face class was closed because of Covid-19. Pre-test consisting six questions, two of them simple question to measure knowledge and comprehension and four of them word problem to measure application and higher ability; were asked to the students.

4.2. Intervention of Lesson

Because of Covid-19 situation, total of twenty-five students of grade eight from one of the schools of Nepal participated in this study. The online experimental class was taught by one of the authors. The lesson structure of the experimental class was composed of Hogan & Forsten, (2007)'s eight steps of model drawing approach guided through interpretation, visualization and mathematical equation in Figure 4.

To see the effect of model drawing and visualization, in total six intervention lessons of word problem were implemented in the topic of application of an equation based on the 8 steps of model drawing. One of the examples given below in Figure 5, was developed by the authors using comparative model.

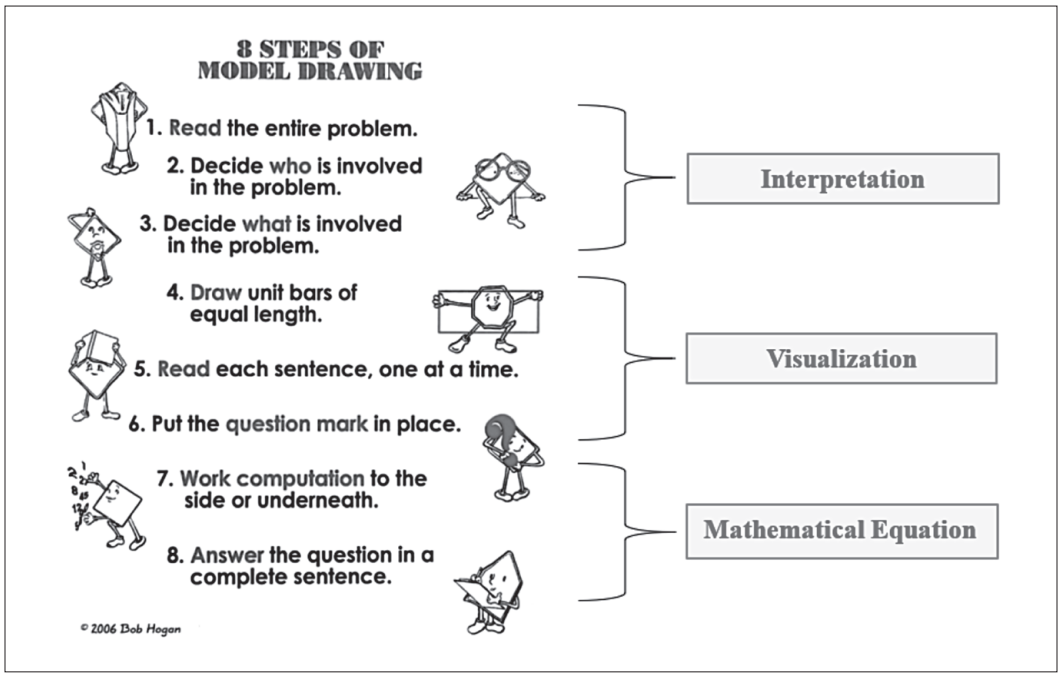

Figure 4. Eight steps of model drawing based on Hogan and Forsten (2007).

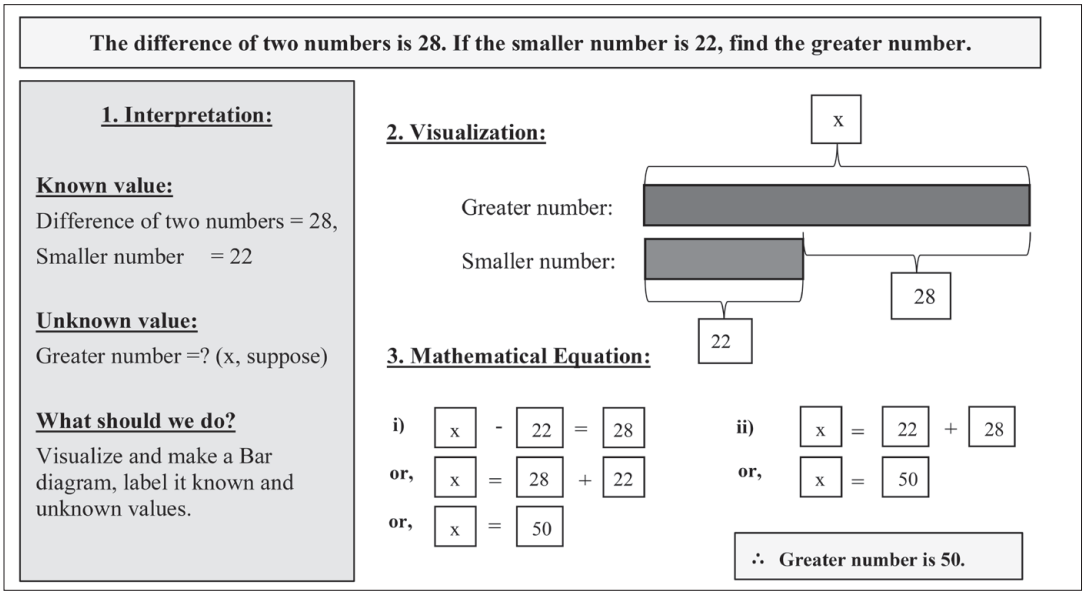

Figure 5. Example of lesson development. Source: Developed by the authors.

4.3. Post-test

Under Covid-19 situation, post-test was conducted through online. Post-test also consisting six questions, one of them simple question to measure knowledge and comprehension and rest of five-word problem to measure application and higher ability.

4.4. Social Validity Survey

After the intervention lessons students of experimental class (EC) were given to fill the questionnaire to know their feelings regarding learning through model drawing and visualization.

5. Discussion of Result

5.1. Quantitative Analysis

For a sample population of twenty-five students (n = 25), pre-test was conducted to measure base line of students. In Table 1 below, it was found that experimental class (EC), had significant difference in pre-test and post-test score.

Table 1. Pre- & Post-Test Comparison.

	Number of Students	Average	Standard deviation
Pre-Test	25	3.16	1.18
Post-Test		5.64	0.64

The above Table 1 suggests that after the intervention lesson, experimental class (EC) had better mean score in a post-test. The standard deviation of EC in a pre-test is 1.18, however standard deviation of same EC in a post-test is 0.64. Because standard deviation of EC in a post-test is less than standard deviation of EC in a pre-test, we conclude that the experimental class (EC) has obtained more consistent scores and better performance because of intervention lesson through the model drawing and visualization.

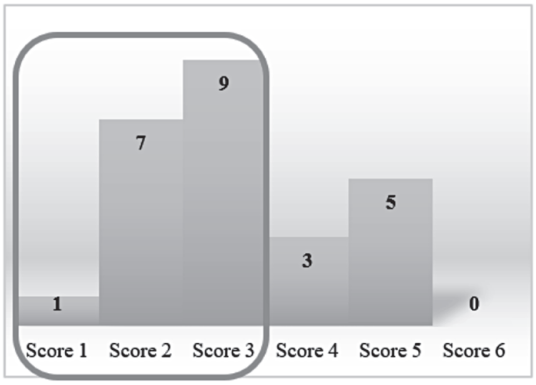

Figure 6. Histogram of score in Pre-test.

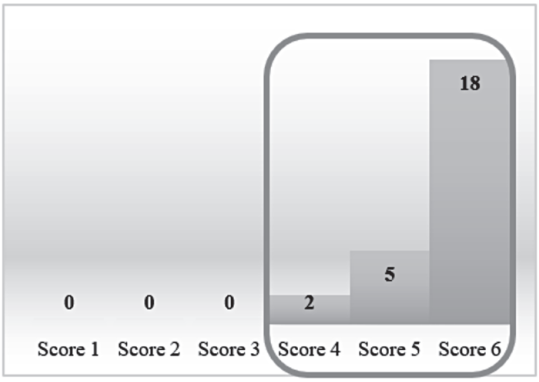

Figure 7. Histogram of score in Post-test.

From Figure 6 above, the scores of students are not distributed normally in a pre-test. We can see that low scorer 1, 2 and 3 consist of 17 students out of 25 students in Figure 6 and after the intervention lesson through model drawing and visualization all of those low scorer students shifted to score 4, 5 and 6 in a post-test in Figure 7, which is good sign of academic performance of students.

Figure 8 and Figure 9, below show students' performance in a post-test was better than pre-test. Questions 2-6 of a pre-test and questions 1-5 of a post-test were similar types of questions. The correct response in knowledge and comprehension types of questions in a pre-test was found 76% however it was 92% in post-test. Also, the correct response in an application and higher ability types of questions in a pre-test was found 41% however it was 94.4% in a post-test.

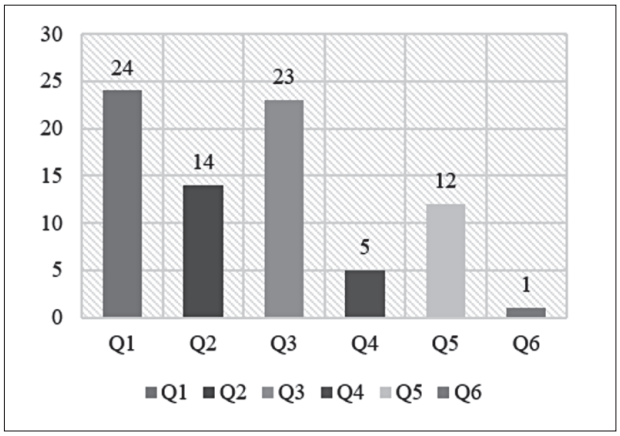

Figure 8. Correct response of students in Pre-test.

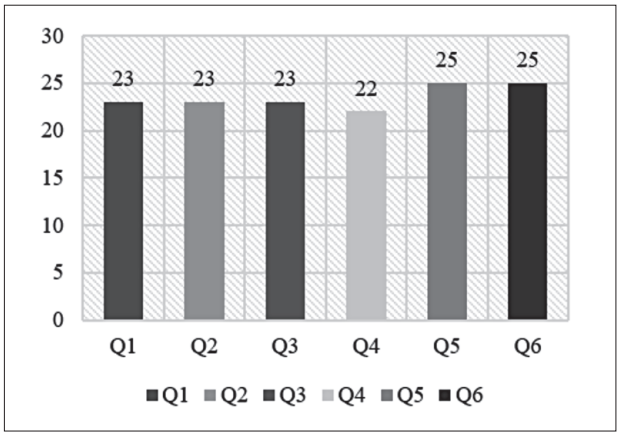

Figure 9. Correct response of students in Post-test.

Table 2 and Figure 10 shows the mean difference in the t-test result. From this result it is clear that the difference in the mean achievement before and after

Table 2. Paired Two Sample for Means.

Null hypothesis Ho	$\mu_{Pr} = \mu_{Po}$
Alternative hypothesis Ha	$\mu_{Pr} < \mu_{Po}$
Samples S.D.	1.1
Observed t-value	-11.091
p-value (left one-tailed test)	0.000
Rationale:	p-value 0.000 < α 0.05

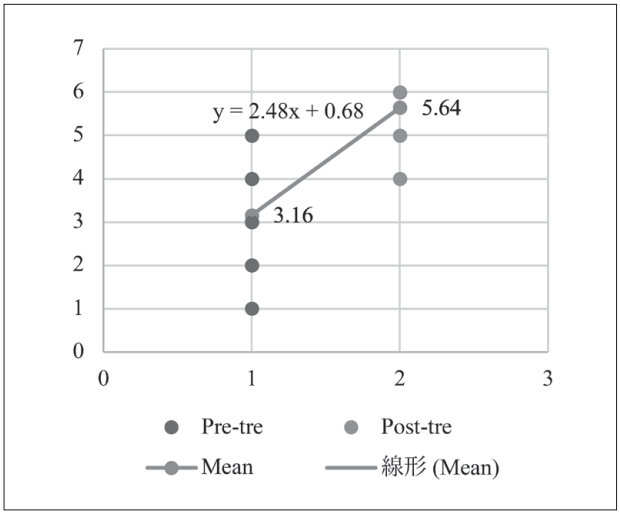

Figure 10. Stratified dot plot of score.

the intervention lessons are statistically significant at 5% significance level. Therefore, we can conclude that the learning achievement after intervention lesson through model drawing and visualization, experimental class (EC) has better knowledge, comprehension, application skills as well as academic performance than before the intervention lesson.

A social validity survey was given to the experimental class. The student's response (n=28) in Figure 11, shows that strongly agree students, 68% likes, and 79% enjoyed the lesson through model drawing. 86% students think that other students of same age should also taught through model drawing. Also, 89% strongly agree that model drawing helps to solve the problem and 86% strongly agree that other students of same age should be taught through model drawing. However, only 4% of students strongly agree that through model drawing they had difficulty to understand the content.

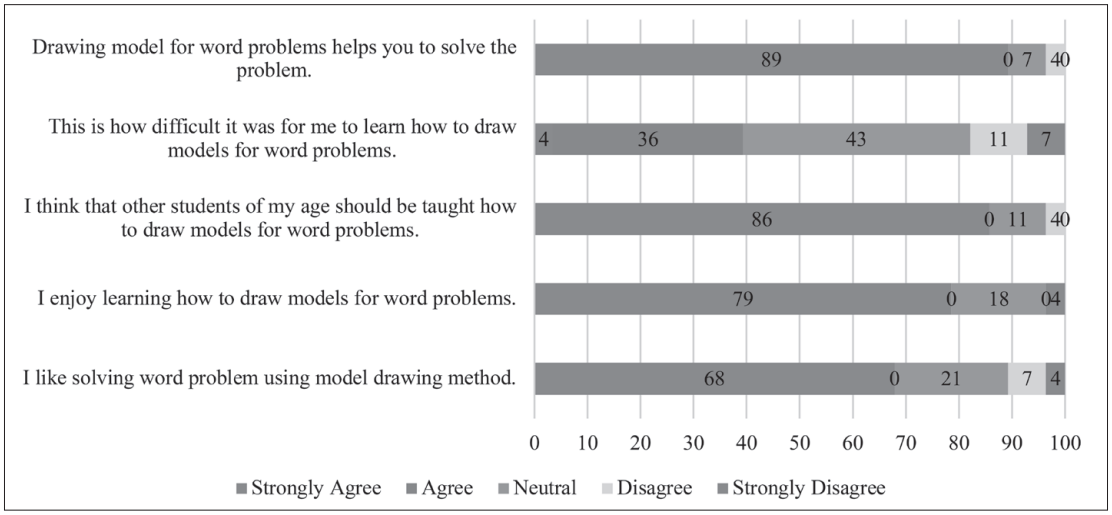

Figure 11. Response of students in a Social Validity Survey.

5.2. How students solved the problem

Here, one of the students randomly selected to show how students understand the problem and use their knowledge and application skills to solve the problem.

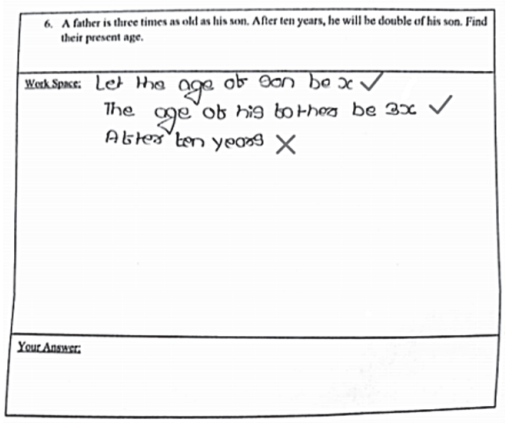

Figure 12. Student solves the problem in Pre-test.

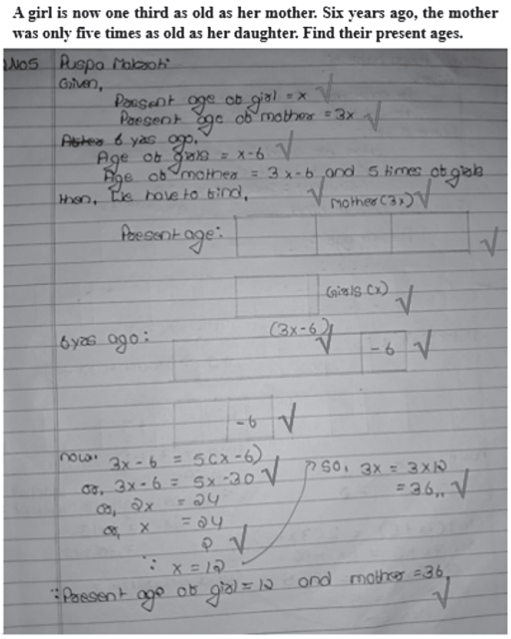

Figure 13. Student solves the problem in Post-test.

Here, one of the students randomly selected to show how students understand the problem and use their knowledge and application skills to solve the problem.

Figure 12 and Figure 13 shows how problem solved by one of the students of EC. Only one student solves this problem in a pre-test implies most of the students had lack of interpretations, visualization, making mathematical equation, and solving problem ability at the time of pre-test. However, after the intervention lesson through model drawing and visualization 25 out of 25 students able to solve same kinds of problem utilizing interpretation, visualization and mathematical equation to arrive at solution in a post-test.

6. Area of further study

The intervention lesson through the model drawing and visualization for experimental class (EC) and through traditional regular approach for controlled class (CC) and their comparison should be further area of this study. Even, the study expects model drawing through visualization will be promising approach to solving word problem of equation. Furthermore, this study will be good guideline for further studies on this field.

7. Potential weakness/challenges of the study

Under Covid-19 situation this study constitutes only 25 students as a sample population which is very small and may not represent the whole population. The intervention lesson was conducted online by one of the authors using zoom and google classroom platform and online post-test conducted for students.

All data for this study collected through online may not represent actual circumstances like data collected through face to face. Also, this study is based on only one school of Nepal so we cannot generalize this result for all the schools of Nepal. Some of the challenges faced on online data collection that cannot be ignored were listed below:

- Internet connectivity and low bandwidth
- Frequently electricity cut off, no backup
- Drawing bar in a mobile phone
- Individual/pair/group activity
- Interaction among teacher and students
- Possibility of sharing photo
- Chance of copying in a test
- Forgot to submit the answer sheet

8. Conclusion

The few studies carried out so far in Singapore. Ng & Lee (2005, 2009) and Kaur (2019) on model method shows that it helps students to improve their ability in solving arithmetic as well as algebraic word problems. The excellent achievement of Singapore's students in the Trends in International Mathematics and Science Study (TIMSS, 2003, 2019), and also Programme for International Student Assessment (PISA, 2018) has drawn a lot of attention to school mathematics curriculum and textbooks used in Singapore. In several countries, the 'model' method has been emulated in classrooms. However, again there appears to be a dearth of research done on its efficacy in these classrooms. The few studies done so far, Mahoney (2012), and Morin et al. (2017) all reinforce efficacy of the model drawing and visualization.

In this study if we look at the result of pre-post-test, we can say experimental class (EC), has low score in pre-test. However, after the intervention lessons, post-test confirm that EC had better score than before. So, we can conclude from the result of pre- & post-test that because the children were taught through model drawing and visualization approach guided through interpretations, visualization and mathematical equation and solution, students' knowledge, comprehension and application skills becomes better than before and consequently, their academic performance increased.

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