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Effectiveness of Visualisation Integrated Problem Solving Approach on Improving Grade Three Malaysian Students' Arithmetic Word Problem Solving Ability

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Abstract

Problem solving serve as the centre piece of mathematical instructions in elementary school. However, tackling word problems remains one of the most challenging tasks for students. This study is conducted to determine the effectiveness of visualisation integrated problem-solving approach on improving grade three Malaysian students' arithmetic word problem solving ability. This quasi-experimental research involved 59 Grade Three students from National Type Chinese Primary School (NTCPS) selected using multistage cluster sampling. The hypothesis of the study is tested by performing independent samples t-test. The findings indicate that visualisation integrated problem-solving approach is effective in improving students learning and retention in solving arithmetic problems. Teachers are encouraged to guide students in using schematic diagrams to illustrate the problem context and relationships between numerical information. This not only helps students apply their conceptual knowledge more effectively but also equips them with a practical tool for problem-solving in real-world contexts.

Keywords: Arithmetic, Word Problem, Problem Solving, Visualisation, Elementary School

Introduction

Technology revolution witnessed drastic change of human life in various aspect. Many routine tasks are gradually replaced by mechanized labour due to its cost-effective feature. Thus, the future workforce with high problem-solving skill is on demand in the job market to thrive in this technological era. In fact, problem solving has been integrated into mathematics curriculum since early of twentieth century with the concern of connecting mathematics learnt in school with students' life outside the school (Hiebert et al., 1996). Rather than acquiring the mathematical skills, the students are required to make sense of the mathematical knowledge and apply it to solve the problem. This movement eventually put problem-solving as the ultimate goal in mathematics classroom (Liljedahl et al., 2016).

To support students making sense of mathematics knowledge learnt in the classroom, problem solving serve as the centre piece of mathematical instructions in elementary school. The students would be challenged to solve the word problems that contain the textual form problem situation embedded with at least one questions that can be answered by applying arithmetic operations on the numerical data retrieved from the problem situation (Verschaffel et al., 2000). In mathematics textbooks, the arithmetic word problems are commonly presented at the end of each arithmetic topics. By solving this question, the students would apply the arithmetic knowledge acquired. This eventually promotes a higher level of mathematical learning.

Despite the emphasis of problem solving in mathematics curriculum, the teaching of problem solving mainly focuses on applying the generic heuristics proposed by Polya (1945) during the process of solving word problems (Foster, 2023; Leong & Janjaruporn, 2015). The students are taught to solve the word problems following the heuristics proposed by Polya (1945): (i) understand the problems; (ii) devise the plan; (iii) carry out the plan; and (iv) look back and reflect. While these heuristics are domain-general, the students will try to apply them in solving the problem-solving task of the it has been posted by the teachers in the classroom (Foster, 2023; Kojo et al., 2018). Meanwhile, the teacher serves as the facilitator who scaffolds students in solving the word problems (Tay & Toh, 2023). This problem-solving instruction is regarded as the conventional problem-solving approach in this study.

While teaching problem solving is a key focus in mathematics classrooms, tackling word problems remains one of the most challenging tasks for students (Verschaffel et al., 2020). Although the students have learnt about the arithmetic concepts and procedures of performing arithmetic operations, they failed to apply the knowledge to solve the word problems. The students' poor achievement in solving arithmetic word problems is a common issue worldwide. Based on the results of Trends in Mathematics and Science Study (TIMSS) 2019, majority of the elementary students from the participated country could apply basic mathematical knowledge in simple situations (Mullis et al., 2020). However, less than 50 percent of these students could apply conceptual understanding to solve problems in TIMSS 2019 (Mullis et al., 2020). In other words, most of the students could solve the routine word problems but fail to solve the non-routine word problems. Likewise, Suseelan et al. (2023) also found that most of the Malaysian students only achieved minimal proficiency in solving complex word problems.

The poor performance of students in solving word problems could be due to their poor understanding about the problem context and quantitative relationships between the numerical information of the word problems (Chin & Chew, 2022, 2023; Mason, 2018). With this regard, incorporating strategies such as visualization can offer an effective way to simplify and better understand the problem-solving process. In fact, schematic diagram drawn could serve as a tool to representing and the problem context and the relationship between the numerical information in the whole number arithmetic word problems (Kaur, 2019). Consider the following word problem '*A store sold 45 apples on Monday. The apples being sold on Tuesday is 30 more than Monday. Meanwhile, the apples being sold on Wednesday is twice the number of apples on Tuesday. How many apples did the store sell over these three days?*', the students represent the problem context using schematic diagram and illustrated the relationship between the numerical information using model as shown in Figure 1. By visually representing each part of the problem, students can better grasp the relationships between the numbers and then proceed to calculate the total by adding all three days (45 + 75 + 150), resulting in 270 apples.

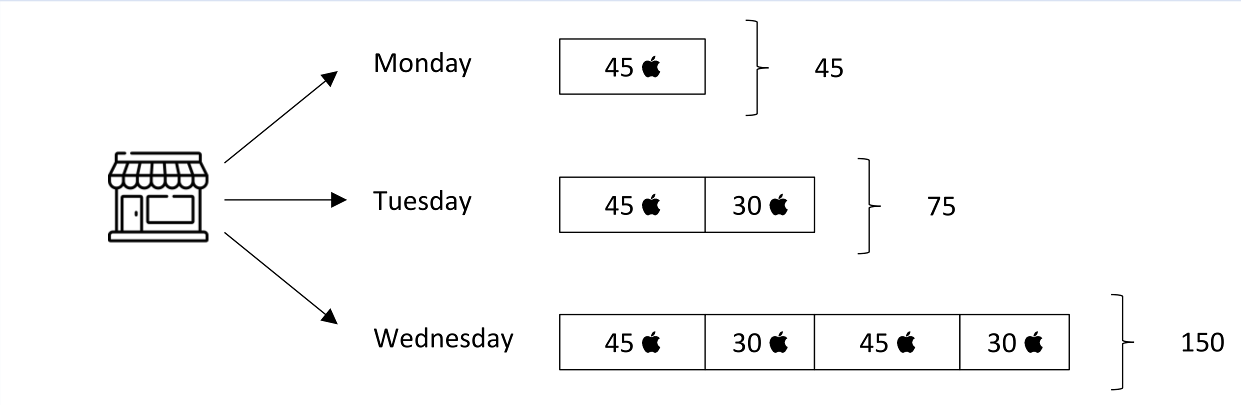

Figure 1. Schematic Diagram

The effectiveness of using visualisation in solving word problems have been reported by several studies. The study conducted by Lowrie (2020) indicates that the use of diagrammatic solutions increases the likelihood of a student in obtaining the correct answers when solving word problems. Likewise, Said and Tengah (2022), as well as Schoen (2019), also found that the use of visual representations while problem solving significantly increases student's achievement in solving word problems. De Koning et al. (2022), extend the past studies by testing the effectiveness of visualization technique, named bar diagram drawing for solving inconsistent word problems that contain the terminology or phrases (i.e., "three times more than") that might lead to wrong arithmetic operation used. The result indicated that the approach is effective in supporting students solving inconsistent word problems. However, the results in mediated by the diagram accuracy, whereby the wrong answer will be obtained if the inaccurate diagram were drawn.

Problem solving is the focus in mathematics classrooms. However, research constantly revealed the poor performance of students in solving word problems. This indicates there is a crucial need for interventions that could help students master the mathematics word problems. To address this issue, visualisation is integrated with the problem-solving heuristic with Polya (1945) in order to support students in solving arithmetic word problems. This approach is regarded as visualisation-integrated problem-solving approach. Specifically, this study sought to determine the effectiveness of visualisation-integrated problem-solving approach on improving grade three Malaysian students' arithmetic word problem solving ability. Different with the previous study, this study focuses on both achievement and retention of students in solving arithmetic word problems. Thus, this study would be able to contribute to literature gaps and the findings of this study would encourage the teacher to adopt this approach in teaching arithmetic word problems.

Research Questions

RQ1: Is there any significant difference in arithmetic word problem solving ability among the students in control group (conventional problem-solving approach) and the students in experimental group (visualisation-integrated problem-solving approach)?

RQ2: Is there any significant difference in the retention of arithmetic word problem solving ability among the students in control group (conventional problem-solving strategies) and the students in experimental group (visualisation-integrated problem-solving approach)?

Hypotheses

H_o1: There is no significant difference in arithmetic word problem solving ability among the students in control group (conventional problem-solving approach) and the students in experimental group (visualization integrated problem-solving approach).

H_o2: There is no significant difference in retention of arithmetic word problem solving ability among the students in control group (conventional problem-solving approach) and the students in experimental group (visualization integrated problem-solving approach).

Method

Research Design

Quasi-experimental research design is adopted as the research design of this study because the students were unable to assign into experimental and control group on random (Gay et al., 2012). Specifically, this study was conducted using non-equivalent control group pre-test post-test design as shown in Table 1.

Table 1
Research Design

Group	**Pre-test**	**Treatment**	**Post-test**	**Delayed Post-test**
Control Group	O_1	X_1	O_2	O_3
Experimental Group	O_1	X_2	O_2	O_3

Note. O_1 = Pre-test of arithmetic word problem solving ability, O_2 = Post-test of arithmetic word problem solving ability, O_3=Delayed post-test of arithmetic word problem solving ability, X_1 = Conventional problem-solving approach, X_2 = Visualization integrated problem-solving approach

Research Participants

The research participants are the 59 Grade Three students from National Type Chinese Primary School (NTCPS) selected using multistage cluster sampling. The sampling process began with selecting two NTCPS in Penang randomly based on the list of school given by the Penang State Education Department. Then, a total of 59 Grade Three students from the two intact classes were selected randomly from the two schools during the second stage of the sampling process. The demographic information of the research participants is tabulated in the Table 2.

Table 2
Research Participants

Group	**Male**	**Female**	**Number of Participants**
Control Group	16	14	30
Experimental Group	16	13	29

Total	32	27	59

Research Instrument

The research instrument of this study is the arithmetic word problem solving ability test (AWPST) that are developed into three equivalent tests, namely pre- AWPST, post-AWPST, and delayed post-AWPST. The three sets of AWPSTs consist of the same 10 arithmetic word problems that are arranged in different sequences. As the constructed response test, the students would have to show their work on the AWPST booklet. The duration of the test is 60 minutes. After the test development process, the AWPST was validated by three experienced mathematics teachers from NTCPS. This was followed by conducting pilot study in a school. The result of instrument reliability analysis (i.e., Cronbach Alpha = .82) indicated that the measurement made using AWPST is reliable (George & Mallery, 2019).

Research Procedure

Before conducting the research, the permission to approval to conduct research was obtained from the Educational Planning and Research Division (EPRD), the state education department, as well as the headmaster of the participated school. The first phase of the research involves administration of the pre- AWPST to the students from both control and intervention group before they learn the topic of arithmetic operation. This is because the word problems are embedded in the topics. One week after pre-AWPST administration, the four-week intervention session began. For each week, the students will attend six 30-minutes intervention session. In each intervention session, the students in the experimental group were taught using visualization integration problem-solving approach, while the students in control group were taught using conventional problem-solving approach. The post-AWPST was given to the participants in both groups by the researcher a week following the intervention sessions. To determine the retention of the knowledge, the delayed post-AWPST was given to the participants in both groups two weeks after the administration of post-AWPST.

Result

To address the research questions of this study, hypothesis testing was performed using Statistical Package of Social Science (SPSS) version 27. The normality assumption was tested based on the skewness and kurtosis of the data reported in Table 3. While the skewness of the students' scores in pre-AWPST, post-AWPST, and delayed post-AWPST for both groups ranged from 1.50 to 1.50, the data could be assumed to be normally distributed (George & Mallery, 2019).

Table 3
Skewness and Kurtosis

Data set	**Skewness**	**Kurtosis**
Control Group		
Pre- AWPST	-0.90	-0.16
Post- AWPST	-0.99	0.07
Delayed post-AWPST	-1.15	0.20
Experimental Group		
Pre- AWPST	-1.37	3.93
Post- AWPST	-0.93	0.32

Delayed post-AWPST	-1.50	1.71

The descriptive statistics of students' scores in pre-AWPST for control and experimental group were tabulated in Table 4. Before receiving the intervention, the average pre-AWPST score of the students in control group is 25.57 (*SD=3.91*), whereas the average pre-AWPST score of the students in the experimental group is 24.75 (*2.86*). Before performing the independent samples t-test to determine the equality of both groups, the homogeneity assumption of group variance was assessed by performing Levene test. As shown in Table 5, the homogeneity assumption was not violated (*p*=.10 (>.05). The result of independent sample t test indicated that no significant difference of mean pre- AWPST scores were found, *t*(57)=-0.94, *p*=.35 (>.05). The students' arithmetic word problem solving ability in both groups could be assumed to be equal.

Table 4
Descriptive Statistics of Pre-AWPST

Data set	Mean	Standard Deviation
Control Group	25.57	3.91
Experimental Group	24.75	2.86

Table 5
Result of independent samples t-test of the pre- AWPST

Levene's Test for equality of Variances			t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Differences	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Equal variances assumed	2.79	.10	- .94	57	.35	- .77	.82	-2.42	.87
Equal variances not assumed			- .95	55.89	.35	- .77	.82	-2.41	.87

The descriptive statistics of students' scores in post-AWPST for control and experimental group were tabulated in Table 6. After receiving the intervention, the average pre-AWPST score of the students in control group is 25.97 (*SD=3.79*), whereas the average post-AWPST score of the students in the experimental group is 27.79 (*2.12*). Before testing the hypothesis Ho1, the homogeneity assumption of group variance was assessed by performing Levene test. As shown in Table 7, the homogeneity assumption has been violated with *p*=.00 (<.05). The result of independent sample t test indicated that mean difference of post- AWPST scores were found to be significant favour towards the experimental group with *t*(45.92)=- 2.29, *p*=.03 (<.05). This indicates that visualization problem solving approach could be more effective than the conventional problem-solving approach on students arithmetic problem-solving ability.

Table 6
Descriptive Statistics of Post-AWPST

Data set	Mean	Standard Deviation
Control Group	25.97	3.79
Experimental Group	27.79	2.12

Table 7
Result of independent samples t-test of the post- AWPST

Levene's Test for equality of Variances			t-test for Equality of Means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean Differences	Std. Error Difference	95% Confidence Interval of the Difference Lower	Upper
Equal variances assumed	8.05	.00	2.27	57	.03	1.83	.80	.22	3.44
Equal variances not assumed			2.29	45.92	.03	1.83	.80	.22	3.44

The descriptive statistics of students' scores in delayed post-AWPST for control and experimental group were tabulated in Table 8. After two-week gaps, the average delayed post-AWPST score of the students in control group is 26.97 (*SD=3.24*), whereas the average delayed post-AWPST score of the students in the experimental group is 28.72 (*1.58*). Before testing the hypothesis Ho2, the homogeneity assumption of group variance was assessed by performing Levene test. As shown in Table 9, the homogeneity assumption has been violated with p=.00 (<.05). The result of independent sample t test indicated that mean difference of post- AWPST scores were found to be significant favour towards the experimental group with $t(42.33)=-2.66$, p=.01 (<.05). This indicates that visualization problem solving approach could be more effective than the conventional problem-solving approach retention of arithmetic problem-solving ability.

Table 8
Descriptive Statistics of Delayed Post-AWPST

Data set	Mean	Standard Deviation
Control Group	26.97	3.24
Experimental Group	28.72	1.58

Table 9
Result of independent samples t-test of the delayed post-AWPST

Levene's Test for equality of Variances			t-test for Equality of Means						
	F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Differences**	**Std. Error Difference**	**95% Confidence Interval of the Difference Lower**	**Upper**
Equal variances assumed	12.26	.00	2.63	57	.01	1.76	.67	.42	3.09
Equal variances not assumed			2.66	42.33	.01	1.76	.66	.42	3.09

Discussion and Conclusion

This study is conducted to determine the effectiveness of visualisation problem solving approach on improving grade three Malaysian students' arithmetic word problem solving ability. The findings of the study indicated that visualization problem solving approach could be more effective than the conventional problem-solving approach on improving students' arithmetic problem-solving ability and the retention. The findings of this study are supported by the previous studies conducted by De Koning et al. (2022), Lowrie (2020), Said and Tengah (2022), and Schoen (2019).

Visualization problem solving approach could be more effective than the conventional problem-solving approach on improving students' arithmetic problem-solving ability and the retention because it is not sufficient if the students know the process of solving the problem. Even though they could understand the problem, they might not be able to transform the problem into mathematical sentence (Chin & Chew, 2022, 2023) that involves visual representation skills and logical reasoning skills (Boonen et al., 2014; Strohmaier et al., 2022; Reinhold et al., 2020). In another words, they might not be able to proceed with devising the plan to solve the word problem even though they have read and understood the word problem.

By using visualisation approach, the students would apply their knowledge of mathematics concepts to analyse the problem situation and create a representation that helps them to reason the relationship between the numerical information in the arithmetic word problems (Kaitera & Harmoinen , 2022; Lisarelli & Polli, 2022). Based on the schematic diagram drawn, the students would be able to deduce the arithmetic operations needed and hence formulate the mathematical sentences that required to solve the word problems. Thus, visualization problem solving approach could support students in seeking the solution after reading the word problem.

In conclusion, the findings highlight that the visualization approach is effective in helping students solve arithmetic word problems. Teachers are encouraged to guide students in using schematic diagrams to illustrate the problem context and relationships between numerical information. This not only helps students apply their conceptual knowledge more effectively but also equips them with a practical tool for problem-solving in real-world contexts.

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