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TO DETERMINE THE EFFECT OF POLYA'S TEACHING METHOD ON STUDENTS' ACADEMIC ACHIEVEMENT IN THE SUBJECT OF MATHEMATICS AT SECONDARY SCHOOL LEVEL

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Abstract
The current research study intended to determine Polya's teaching method effectiveness on word problems and enhancing problem solving ability in mathematics of the students at secondary school level. Polya's teaching method consist of four steps understanding the problem, devising a plan, carrying out the plan and looking back respectively. Study objectives were: (i) To determine the effect of Polya's Teaching Method on students' academic achievement in the subject of Mathematics at secondary school level; (ii) To find out the effect of Polya's Teaching Method on students' Problem Solving ability in Mathematics at secondary school level. Equivalent group, pre-test post-test design was used in this study. Population of the study consists of all secondary school male students studying mathematics in public sector schools. Sample of 60 students of grade 9 were selected through simple random sampling technique from Government High Secondary School No.1 Nowshera Kalan. On the basis of pretest, using paired random sampling technique sample students were divided into experimental group and control group. For data collection pretest and posttest were used. Collected data were analyzed through mean, standard deviation, variance, dependent T-test and independent T-test. Study results illustrates that Polya's teaching method had significant effect on problem solving ability in solving words problems in mathematics. It is also concluded that Polya's teaching method had significant effect on the academic achievement of students in mathematical word problems at secondary level. The current study may be helpful for the secondary school students to develop their word problems solving ability in mathematics. It offers an alternate method of teaching for teacher to teach mathematics subject.

Keywords: *Polya's Teaching Method, Mathematical word problems, Academic achievement, Problem Solving ability.*

Introduction

Golji and Dangpe (2016) stated that mathematics is the study of numbers, shapes and how things are arranged. We use it in every part of life because it helps us understand the world. It plays a big role in engineering, art, banking, sports and both old and new architecture. Besides being important for science and technology, math is also useful for everyone, whether they are literate or illiterate. People use it every day when they buy and sell things, travel to different places or run businesses.

It was noticed that even spending more than nine or ten years in learning of mathematics, the students are unable to apply it in their real life. The reasons for this may be numerous, but method of teaching is one of the main reasons for this effect as

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cited by Amirali (2011) in the analysis of his work, he discussed difficulties of learning faced by students in the subject of mathematics and pointed out that mostly teachers follow textbook strictly. Mainly teachers assess students by testing their basic recall skills instead of encouraging deeper understanding. Students receive only surface-level knowledge without truly understanding the subject in depth. They teach by using rote memorization and traditional methods, which limit students' thinking. In Pakistan, math education focuses on memorizing rules, following fixed steps, and solving textbook problems (VanHattum, 2011).

In mathematics there can be routine and non routine problem. The problem that contains at least one of the operations of arithmetic and are practical in nature are routine problems (Altun, 2001), on the other hand, the problems concerned with raising the understanding that math is an innovative subject matter and to develop mathematical reasoning of the students are non-routine problems (Polya, 1966).

George Polya is credited with establishing a contemporary emphasis on problem-solving in mathematics. "How to solve" is his best-known work, but he was also an esteemed mathematician and the author of numerous publications on the subject of mathematics. In his book, he suggested a method with four steps for solving problems. Weber (2008) claimed that this type of instruction has attained huge popularity. This method is most widely used for improving problem-solving abilities.

In the words of Polya (2004) problem solving is one technique of developing mathematical problem-solving abilities. It assists students in becoming self-directed learners who can apply maths to problems they encounter on a daily basis. It is a systematic four-step process that solves mathematical problems in an organized manner.

First Step Problem Understanding

This step involves understanding the given problem in relation to the given data. It may be necessary to ask and create figures and diagrams in order to comprehend a number of queries. The nature of the issue determines each of these questions (Polya, 2004).

Second Step Devising a Plan

At this point students are motivated to discover connections amid the known and the unknown data. This phase offers a more thorough comprehension of the problem at hand. Students are urged to think of a problem of an identical sort for this. Students are invited to recollect and answer a similar problem if they are aware of one. It could take a while and be challenging to go from comprehending the issue to coming up with a solution. A "bright idea" or an "auxiliary problem" might be used to develop the plan for problems (Polya, 2004).

Third Step Carrying out the Plan

After second step follow carefully, options made are now put into practice in order to find a solution. It's not always easy to come up with a strategy or a concept for a solution. It requires a lengthy workout. On the other hand, execution is simple. The strategy gives broad guidelines for implementation; however, we must add data to determine whether or not it is effective (Polya, 2004).

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To solve the problem, if the learners develop a plan, it is advantageous for the teacher because a lot of work has already been completed. Students forgetting the plan are the main risk at this point, although this happens when they borrow it. They feel satisfied when they progress as individuals (Polya, 2004).

Fourth Step Looking back

In order to validate their answer, students must now apply it to a new setting. Students look for new motives in this step and attempt to double-check their results by contrasting the known and the unknown. To further develop their knowledge and build the capacity to solve such cases on their own in daily life, one must step back and review, reexamine the outcomes and the solution process. The teacher must clarify that the problem's answer is only a milestone that must be reached; it is not the end point (Polya, 2004).

Rational of the Study

The worldwide educational system has seen tremendous growth in recent years, particularly in developing countries. These countries are interested in changing learning and teaching processes and using innovative techniques in mathematics. Several nations have sought to make appropriate changes to teaching techniques in order to cope with the rapid changes in knowledge and information domains. As a result, new ways to developing and updating instructional procedures and solving mathematics problem are discovered. These methods emphasize the position of the student places him or her at the center of the learning process. It is believed that if learning settings, as well as teaching techniques, are appropriate for each student's skills and requirements, he or she may learn and achieve success. However, in Pakistan we are far behind, and used old style of teaching methods. In order to fill the gap and enhance students problem solving abilities, the development of new problem solving approaches, tactics, and strategies are required. The Polya's teaching method is one of these new way and ideas. Current research study was therefore, designed to identify the effectiveness of Polya's teaching method on the performance and problem solving ability of grade-IX students of district Nowshera studying the subject of Mathematics.

Literature Review

The capacity to solve problems is a skill that is sometimes produced through the problem-solving approach, which enables students to become autonomous learners and solve difficulties in everyday life. Over the past few decades, Polya's approach to problem solving has gained popularity and demonstrated itself to be the most effective way to develop problem-solving skills (Yuan, 2013).

Problem solving in the subject of mathematics is a skill like climbing, riding and swimming etc. It is considered as the internal inborn function of human brain that is enhanced by the mean of a number of methods related to solving a problem. Problem solving is not restricted to a single definition or a single method (Polya, 1953).

According to Polya (1977) compared problem solving to swimming, claiming that it is a practical skill and can be strengthen by practicing more and more like swimming. He claimed that one cannot become a perfect swimmer until and unless that individual goes through a lot of practice and imition of the skill time and again. An individual must follow the instruction of his trainer in order to become a perfect swimmer. In the same way, a student cannot learn how to solve a problem without practice and closely observing his teachers. It is essential for a learner to practice the ability to solve

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problem. A learner needs to understand the processes required in order to solve a problem. According to Polya there are four process that are essential for a learner in order to solve a mathematical problem, these processes include understanding the problem first, after understanding a leaner must devise a plan, after that a plan should be made, and at last looking back also information like possibility, condition, data and unknown circumstances must be analysed. In order to separate parts of circumstances figures could be drawn. In the same way, a clear plan can link the data in hand of unknown data in order reach to the likelihood of outcome of a problem which can be matched with condition of problem. An assessment of how the plan is implemented properly is required in carrying out the plan. It is a cautiously created plan. As a result, these plans need to be carried out analytically. Last but not the least, such questions such as "Can you use the method, or the result for some other problems?" "Can you derive the solution differently?"; "Can you check the argument?"; "Can you check the result?"; "Can you see it at a glance?"; "should be considered in the process of looking back. The processes mentioned by Polya related to solving a mathematical problem enable the students to solve problem by the mean of systematic questioning that is useful for the students in their learning of mathematics.

According to Betne (2010) "Concept formation and discovery learning are components of problem solving". According to Polya (1973) "One method for improving mathematical problem-solving skills is development of problem-solving techniques. It helps the pupils to become self-directed learners and solve mathematical difficulties in everyday life. Higher level skills like analysis, synthesis, assessment, and creativity are developed as a result of this."

According to Temel and Altun (2020) Problem solving involves more than just getting the right answer; it involves a wider range of abilities and thought processes. Since people, who learn to solve problems can apply this ability to any aspect of their lives, making life easier. Teachers are primarily responsible for ensuring that pupils learn these exceptional skills in the most effective and efficient manner possible.

Polya cited by Lidinillah (2012) that the ability to solve problems is a crucial component of intelligence, and that it is a quality that human's value and that can be acquired through experimentation or imitation. Both routine and non-routine situations can encourage imitation and experimentation. Therefore, the capacity to solve mathematical issues, both routine and non-routine, can be defined as mathematical problem ability. As according to Yudhanegara and Lestari (2017) being able to answer both routine and non-routine issues, both applied and non-applied in the subject of mathematics, is known as problem solving ability. The kind of mathematical problem that is presented will guide the student through the process of solving the problem. There is no doubt that the calculation practice differs between the normal and non-routine methods of issue resolution. Both routine problems that call for more algorithmic computation and non-routine problems that are not just applications of formulas, theorems, or assertions must be planned.

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Rudman and Peter (2007) conducted a research study on polya's model on Japanese students of school level in the subject of mathematics. The main objective of the research was to confirm an organizational approach based on the Japanese lesson study model with the help of the Polya problem solving technique. The findings indicated that using the Polya problem solving method to teach improved student accomplishment. Students' understanding and oral and written problem-solving skills improved as a result of this approach. Students' ability to solve difficulties in everyday life also improved.

Problem Statement

In learning of mathematics the teacher role and teaching method are very vital, but empirical evidence provide facts that mostly teachers use drilling formulas, developing computational algorithms, and symbol manipulation deprived of emphasizing on understanding that why these things work. Ali (2011) stated that teachers promote rote learning in student rather than deep understanding. As Farzad (2010) stated Polya's Teaching Method can develop motivation and interest among the students as well as it can made students independent in discoveries and solving problems. It works on Higher Order Thinking. Though, in Pakistan, we remain far behind in order to near the gap, developing new teaching approaches, strategies, and tactics that are vital. Polya's Teaching Method has been adopted as a way of learning in different developed countries. But most of the schools in public and private sector in Pakistan are practicing traditional teaching methods. The drive of this study is to find out the effect of Polya's Teaching Method of teaching on problem solving ability of students as well as academic achievements in mathematics subject at secondary school level.

Objectives of the Study

i) To determine the effect of Polya's Teaching Method on students' academic achievement in the subject of Mathematics at secondary school level.
ii) To find out the effect of Polya's Teaching Method on students' Problem Solving ability in Mathematics at secondary school level.

Hypotheses of the Study

$H_0$1: There was no significant difference between the mean score of control and experimental group on post-test.

$H_0$2: There was no significant effect of Polya's Teaching Method on academic achievements of students in mathematics at secondary school level.

$H_0$3: There was no significant effect of Polya's Teaching Method on students' Problem Solving ability in Mathematics at secondary school level.

Method and procedure

Method plays an imperative part in research work. So, in order to follow research progress there are different methods exist for research work like experimental, historic, case study, descriptive method etc. The researcher used true experimental method in current study.

Population of the Research Study

Secondary school students studying in grade-IX in Khyber Pakhtunkhwa was comprised of population for this current research study. Only public sector male secondary schools were selected as proposed population of the study. In this current study, all male government secondary schools in KP which constitutes 34 districts and has 1436 government schools at secondary level was population of the study. In these

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secondary school 146946 grade-IX students are enrolled (Government of Khyber Pakhtunkhwa, 2022). Though, for this study the target population was all 6488 grade-IX students enrolled in 67 male secondary schools of district Nowshera. Due to experimental nature of study, accessible population was only one secondary school of district Nowshera i.e, Government Higher Secondary School No.1 Nowshera Kalan.
Parameter of the population is given below:

Table : *Parameter of the population*

Total Population	**Government Secondary Schools in KP**	**No of Students in Grade-IX**
	1436	146946
Target Population	**Government Secondary Schools in District Nowshera**	
	67	6488
Accessible Population	**No of Students in Government Higher Secondary School No.1 Nowshera Kalan** 685	 60

Sample of the Research Study

Sample is a limited number of elements selected from the population to be representative of the population. For the conduction of experiment sixty students of Government Higher Secondary School No.1 Nowshera Kalan was selected as sample of the study. These sixty students were divided in two groups by paired random sampling technique on the basis of pre-test. There were 30 male students in each group for this study.
The distribution of sample was as follow;

Table : *Distribution of Sample*

Category	**Number of Students**
Number of students	60
Sample Size	60
Randomly Selected Experimental Group	30
Randomly Selected Control Group	30

Research Design

It was a True Experimental research study and to assess the effectiveness of treatment pretest-posttest equivalent group design was used for this study. Data was collected through achievement test (pre-test and post-test) and problem solving ability test. Two main variables were used in this present research study. Polya's Teaching Method was used as independent variable and student academic achievement and student's problem solving ability were used as dependent variable.
In this study pretest-posttest equivalent group design was used.

Symbolic representation of design is:

$$R_E = O_1 \quad T \quad O_2$$
$$R_C = O_3 \qquad O_4$$

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Where;
R_E= Randomly Selected Experimental Group
R_C= Randomly Selected Control Group
O_1= Pre-experimental test observation
O_2= Post-experimental test observation
O_3= Pre-control test observation
O_4= Post-control test observation
T= Treatment

Research Tool

It is a research instrument for using collecting the data in the research. In this study tests used for gathering the data from respondents, which were pre-tests and post-tests. According to Brown (2004) a test is a tool to assess someone's abilities, expertise, or competence in a certain field. It is a tool as well as a collection of methods, steps, or objects that demands performance from the test-taker. Essay test, restricted response question, completion type, multiple-choice, matching and true-false are the most commonly used test types in education.

Self-made achievement test (pretest-posttest) and problem-solving ability test was constructed from the math textbook for Grade-IX from the chapters (7, 9, 10 & 11). Achievement Test was consist of thirty five (30) Multiple Choice Questions (MCQs) items and five (5) written questions with a total of 50 marks. MCQs were carry equal marks i.e 1 and each written question carry 4 marks each. Problem solving ability test was a written test consist of five (5) written questions included additionally in achievement test targeting to measure student's problem solving ability. Sample students was divided in two group i.e, control and experimental group on the principles of pair random sampling technique based on the mean score of pretest. Likewise, after treatment of six weeks another test (post-test) was taken from the same students, also Problem solving ability test was taken from experimental group.

Treatment

This research was true experimental design. In which two groups control and experimental were developed on the basis of pretest score. Pre-test was a test that held before the treatment. Treatment was given to experimental group for six weeks using Polya's Teaching Method, while control group was taught through traditional way of teaching.

Every treatment class took for forty minutes for four days of a week i.e on Monday, Tuesday, Wednesday and Thursday. Lesson plans were developed to teach Mathematics problems, while control group were taught through a traditional method i.e lecture demonstration method, they did not receive any treatment. Different teachers taught to both groups and both teachers had same qualification with almost same amount experience. Teaching conditions were remaining same for both the groups.

Procedure

In order to collect data, permission obtained from selected school principal. Duration of the experiment was six weeks. A pretest was developed from the text book for the subject of mathematics of grade-IX and administered to the sampled students. Students were divided into two groups on the basis of pretest score. Both groups consist of 30 students each. The subject students was introduced to words problems, Arithmetic, Algebra and Geometry question and teacher starts teaching by applying Polya's first

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step of technique i.e understanding the problem then in second step developing a plan following with third step applying that plan and finally at fourth step looking back to verify the answer. During understanding stage i) cross out information not needed ii) underline important information. During planning stage a strategy was adopted i.e making a drawing, using a formula, working backward etc. For instance, a drawing was draw by the teachers related to the elements of the problem on black/white board and also presented charts and models. During applying stage different strategies (operations) were applied in order to achieve the desired numerical solution. At last stage teacher verified the answer. These steps were followed by students independently and practiced on different questions.

Data Collection Procedure

The data was collected through pre-test post-test and delayed test. The pre-test was administered to the learners selected in sample of the study before the commencement of experiment. The students were divided into two equal groups. Both the groups received treatment for six week. On the completion of six week treatment the researcher administered the post-test to both the groups to find out the outcomes of the treatment and to measure the achievements of the students as well as the effectiveness of the boards which are the main objectives of the study.

Statistical Analysis of Data

The data collected from pre-test and post-test were organized and analyzed through t-test (paired t-test and independent t-test). The mean scores were calculated to measure the overall performance of the respondents of both groups. The t-test was applied to measure the significance difference between the experimental and control groups on the scores of the tests at 0.05 level.

Results and Discussion

The collected data were analyzed and interpreted by using t-test in the light of the objectives of the study

$H_0$1. There was no significant difference between the mean score of control and experimental group on post-test.

Table 1 ***Significance of difference between the mean scores of control and experimental group on post-test***

Group	N	Mean	SD	V	df	Independent t-value	Effect
Post-Control	30	24.4	4.48	20.12	58	-4.976	Significant
Post-Experimental	30	31.4	6.12	37.55			

Degree of freedom=58, Significance level = 0.05, Table Value = 2.001

Table 1 exemplifies t-test results for control and experimental group of post-test. The result directed that there was significant difference found between control and experimental group in post-test. The difference between the calculated values of Mean (24.4 and 31.4), standard deviation (4.48 and 6.12) and variance (20.12 and 37.55) were appropriate and similarly calculated t-value was -4.976 which were significant at

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significance level (0.05), hence the null hypothesis is rejected. It means that there was significance difference between the mean score of control and experimental group on post-test and both control and experimental group preformed differently after treatment.

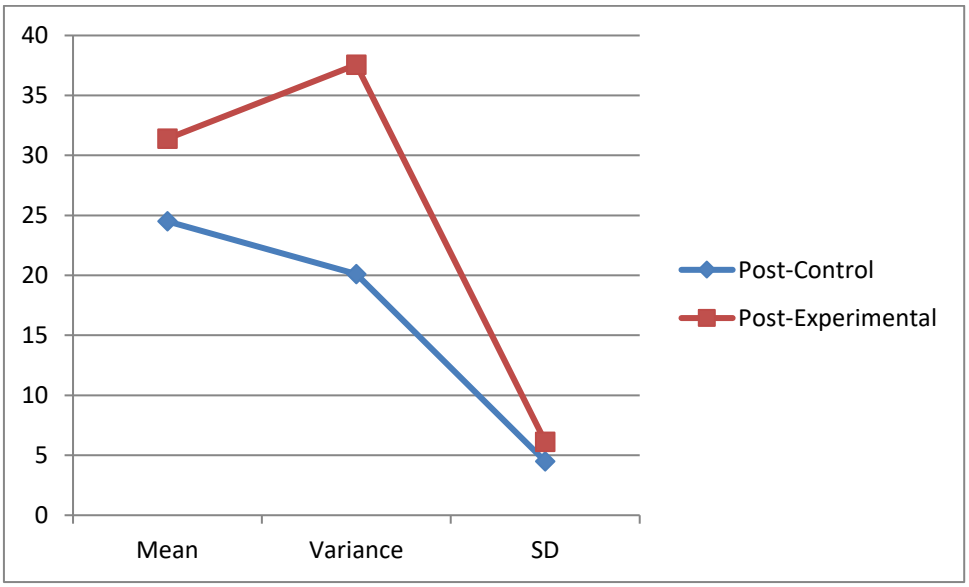

Figure 4.1 *Significance of difference between the mean scores of control and experimental group on post-test*

Table 4.2 *Significance of difference between the mean scores of pre-test and post-test of control group*

Group	N	Mean	SD	V	df	Dependent t-value	Effect
Pre-Control	30	23.83	3.68	13.59	29	-1.63	Not Significant
Post-Control	30	24.5	4.48	20.12			

Degree of freedom=29, Significance level = 0.05, Table Value = 2.045

Table 4.2 represents t-test results for control group of post-test and pre-test. The result showed that there was no significant difference found between pre-control and post-control group in t-test. The difference between the calculated values of Mean (23.83 and 24.5) was negligible, standard deviation (3.68 and 4.48) and variance (13.59 and 20.12) were substantial but calculated t-value was -1.63 which were not significant at significance level (0.05), hence the null hypothesis is accepted. It means that there was no significance difference between the mean score of pre-control and post-control group and after teaching through traditional method of teaching to control group, they were found on same level as before.

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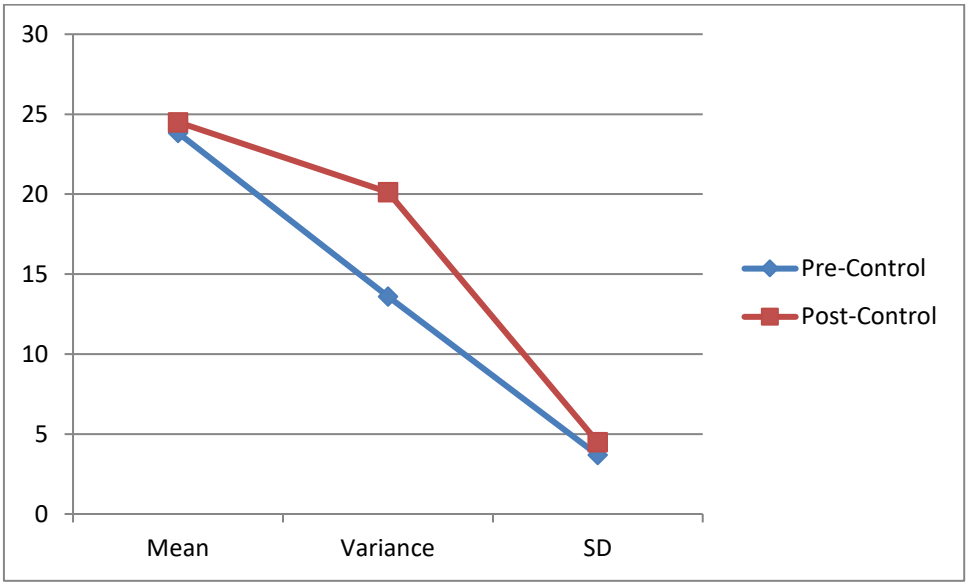

Figure 4.2 *Significance of difference between the mean scores of pre-test and post-test of control group*

$H_0$2. There was no significant effect of Polya's Teaching Method on academic achievements of students in mathematics at secondary school level.

Table 3 *Significance effect of Polya's Teaching Method on academic achievements of students in mathematics at secondary school level*

Group	N	Mean	SD	V	df	Dependent t-value	Effect
Pre-Experimental	30	23.63	3.78	14.30	29	-12.94	Significant
Post-Experimental	30	31.4	6.12	37.55			

Degree of freedom=29, Significance level = 0.05, Table Value = 2.045

Table 3 demonstrates t-test results for experimental group of post-test and pre-test. The result showed that there was significant difference found between pre-experimental and post-experimental group in t-test. The difference between the calculated values of Mean (23.63 and 31.4), standard deviation (3.78 and 6.12) and variance (14.30 and 37.55) were noteworthy and similarly calculated t-value was -12.94 which were significant at significance level (0.05), hence the null hypothesis is rejected. It means that there was significance difference between the mean score of pre-experimental group and post-experimental and after teaching through Polya's Teaching Method of teaching to experimental group, they were found improved after the treatment.

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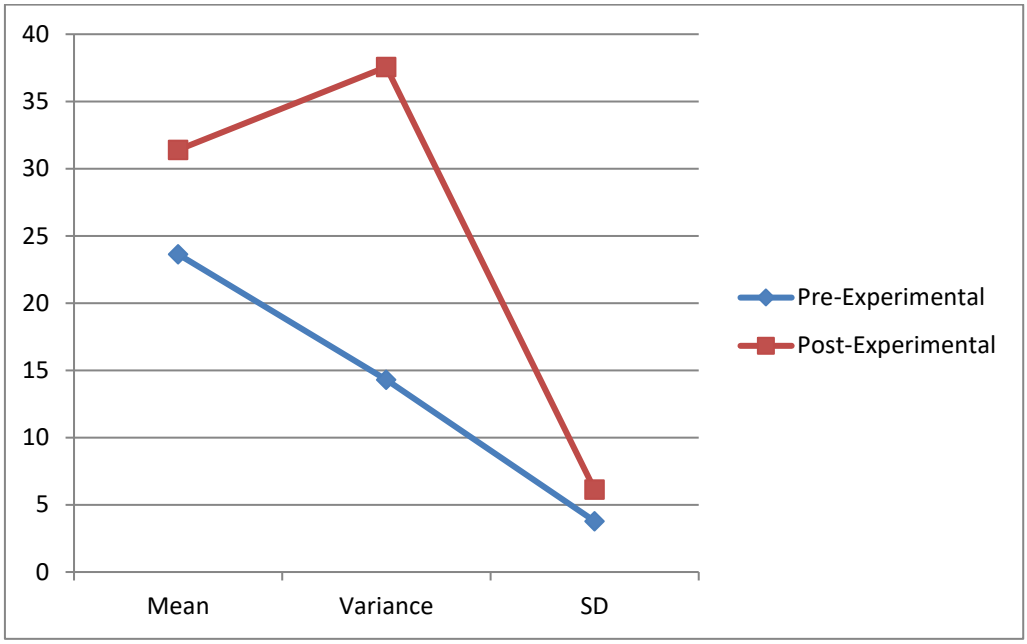

Figure 4.3 *Significance effect of Polya's Teaching Method on academic achievements of students in mathematics at secondary school level*

$H_0$3. There was no significant effect of Polya's Teaching Method on students' Problem-Solving ability in Mathematics at secondary school level.

Table 4 *Significance effect of Polya's Teaching Method on students' Problem Solving ability in Mathematics at secondary school level*

Group	N	Mean	SD	V	df	Dependent t-value	Effect
Pre-Problem Solving Ability	30	3.46	2.08	4.32	29	-11.49	Significant
Post-Problem Solving Ability	30	8.03	2.83	8.03			

Degree of freedom=29, Significance level = 0.05, Table Value = 2.045

Table 4 establishes t-test results for Pre-Problem Solving Ability and Pos-t Problem Solving Ability of experimental group students. The result indicated that there was significant difference found between pre-problem solving ability and post-problem solving ability of experimental group students in t-test. The difference between the calculated values of Mean (3.46 and 8.03), standard deviation (2.08 and 2.83) and variance (4.32 and 8.03) were noteworthy and similarly calculated t-value was -11.49 which were significant at significance level (0.05), hence the null hypothesis is rejected. It means that there was significance difference between the mean score of pre-problem solving ability and post-problem solving ability of experimental group students and after teaching through Polya's Teaching Method of teaching to experimental group, they were found improved in problem solving ability.

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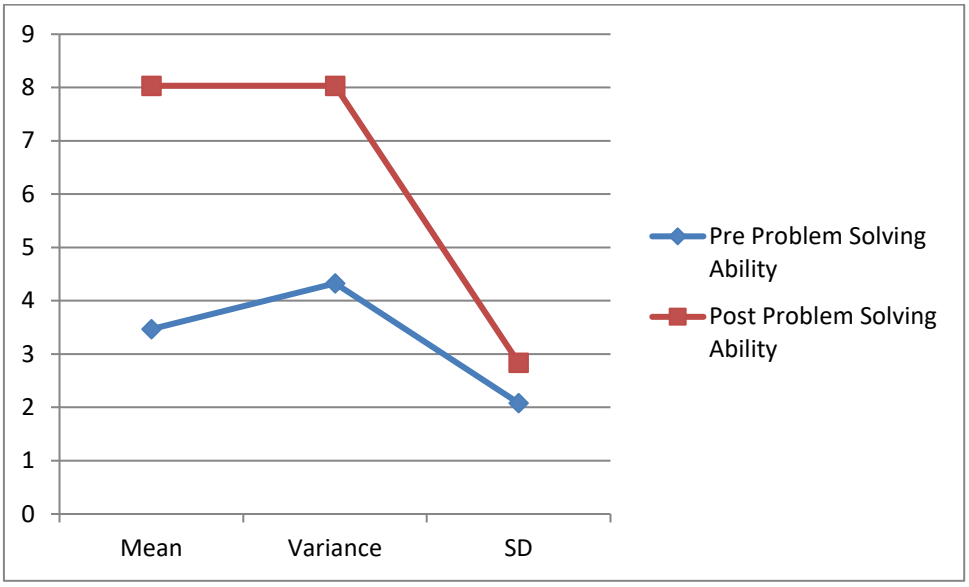

Figure 4: *Significance effect of Polya's Teaching Method on students' Problem Solving ability in Mathematics at secondary school level*

Discussion

The present study was intended to determine Polya's teaching method effectiveness on word problems in mathematics subject at secondary level. Following were objectives of the study (i) to determine the effect of Polya's Teaching Method on students' academic achievement in the subject of Mathematics at secondary school level, (ii) to find out the effect of Polya's Teaching Method on students' Problem Solving ability in Mathematics at secondary school level.

Secondary school students studying in grade-IX in Khyber Pakhtunkhwa was comprised of population for this current research study. Ongoing study was delimited to sixty students of GHSS No.1 Nowshera Kalan. These sixty students were divided in two groups by paired random sampling technique on the basis of pre-test. There were 30 male students in each group for this study.

Achievement test (pretest-posttest) and problem-solving ability test were developed by the researcher as research tools for data collection in consultation with subject experts and supervisor. Lesson planes were developed and delivered by researcher and teachers respectively. Collected data were tabulated, analyzed and interpreted using dependent t-test and independent t-test formulas.

Mostly, this study focus remained on to inquire Applying Polya's Teaching Method in Solving Word Problems in Mathematics at Secondary School Level. The link between the Polya's teaching method and traditional method had been developed with a pretest, posttest equivalent group design. The controlled group had been planned with the traditional class teaching. The treatment had remained in practice for the period of six weeks. The results of the study were in favor of the Polya's teaching method in enhancing academic achievement and problem solving ability.

Conclusions

i. From the results it was established that Polya's teaching method had significant effect on the academic achievement of students in mathematical word problems at secondary level.

ii. The result of study showed that Polya's teaching method had significant effect on the problem solving ability of students in mathematics at secondary level and student improved with solving word problems skill after treatment.
iii. From the results it was concluded that Polya's teaching method had also significant effect on the high achievers students as well as low achievers students in mathematics subject at secondary level. So it showed that Polya's teaching method is not just improve the problem solving ability of active learners but it can also improve problem solving ability of slow learners.
iv. The study found that teaching of Mathematics through Polya's teaching method was more effective than traditional teaching approach.

Recommendations

i. As the study shown that Polya's teaching method has strength over the traditional method, so it is recommended that teacher should use Polya's teaching method in teaching of mathematics subject during classroom. For this it may be added in pre-service and in-service training programs.
ii. Study showed that Polya's teaching method developed the ability of problem solving in students, therefore it is recommended that in-service training should be provided to teachers who's teach mathematics at secondary level.
iii. It is also suggested that in-service training should be provided to elementary school teachers for their importance of developing the base in mathematics.
iv. It is also suggested that developers of curriculum should give primacy to embrace Polya's teaching method into teacher training programs such as pre-services training and currently ongoing induction training. Directorate of professional development should ensure its implementation in these teachers training programs.
v. The current study had been conducted in male's school in district Nowshera, but similar study could be successfully applied in female's schools also.

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