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# Effectiveness of Polya's Heuristic Approach To Problem Solving In Acquisition of Mathematical Concepts Among Secondary School Students With Different Study Habits

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**Abstract**

The present investigation was undertaken with an aim to study the effectiveness of Polya's heuristic approach to problem solving in acquisition of mathematical concepts among secondary school students with different study habits. For this purpose 320 secondary school students from Moga district of Punjab state were taken as a sample. The tools used were Mathematical Concept Acquisition Test (developed by the investigator on selected topics of Mathematics of Grade IX) and Revised Study Habit Inventory by Mukhopadhyay and Sansanwal (2011). Instructional material (Modules) based on Problem Solving Instructional Strategy on selected topics of Mathematics for Grade IX was also prepared by the investigator. It was validated by the subject experts and later on was implemented to the experimental group. The present study employed an experimental method with 2X2 factorial design. Results showed that students taught through were found to achieve significantly high on the acquisition of mathematical concepts than taught through traditional teaching method. No significant main effect of study habits was found on mathematical concept acquisition. Further results revealed that significant interactional effect of instructional strategies and study habits was found on the acquisition of mathematical concepts of grade ninth students. Students belonging to both high and low level of study habits achieve higher when taught by problem solving instructional strategy (PSIS) as compared to those taught by traditional instructional strategy (TIS).

**Keywords:** Polya'S Heuristic Approach, Problem Solving, Acquisition of Mathematical Concepts, Secondary School Students and Study Habits

**Introduction**

Today, qualitative improvement of education is of great importance and it can be achieved only by improving the quality of instruction. Even though great advancement in science as well as educational technology was made in our country, the methods of teaching prevalent are not significant to meet the requirements of the students at all levels. Several studies on classroom practices reveal that even though the student's characteristics and societal expectations have changed, our educators still employ those traditional methods and mode of instruction. Hence, it is necessary to refine and to improve the teaching methods and instructional techniques to realize the fullest potentialities of individual student learning needs and to achieve acceptable levels of individual student mastery, proficiency and expertise.

**Mathematics Teaching-Learning**

An information and technology based society requires individuals to think critically about complex issues, analyze and adapt to new situations, solve problems of various kinds, and communicate their thinking effectively. The study of mathematics equips students with knowledge, skills and habits of mind that are essential for successful and rewarding participation in such a society. To learn mathematics in a way that will serve them well throughout their lives, students need classroom experiences that develop mathematical understanding, learn important facts, skills and procedures, develop the ability to apply the processes of mathematics, and acquire a positive attitude towards mathematics. Learning mathematics results in more than a mastery of basic skills. Students who truly understand or make sense of mathematical concepts are not just manipulating symbols or following rules invented by others to solve problems. They are applying rules and exploring solutions by using logical thinking and reasonableness of solutions. Mathematical structures, operations, processes and language provide students with a framework and tools for reasoning, justifying conclusions and expressing ideas clearly through mathematical activities that are practical and relevant to their lives and, eventually in the workplace.

**Present Status of Teaching Mathematics**

In spite of playing an important and a vital role in our cultural development as well as for individual's progress, mathematics is not a subject of choice for many students. Sufficient attention is not paid to teaching and learning of mathematics. Our board results of past few years tell us the true story, failures in mathematics are increasing day-by-day. Majority of students avoid mathematics and phobia for mathematics is increasing inadvertently.

A major cause for the failure in mathematics is the way in which students learn mathematics rather than the difficulty of mathematics as a discipline. However, the ways in which students learn mathematics depend on the ways in which they are taught by their teachers in the schools and the ways in which it is being presented in the mathematics text-books. The nature of mathematics is being reflected in mathematics curriculum. Present mathematics curriculum does not give much scope to develop mathematical disposition. Moreover most school principals lament about non-availability of competent and committed mathematics teachers in the employment market. Mathematics is taught like a mechanical subject with no originality, creativity and imagination. Students are trained to develop mathematical skills of calculation and construction. They are not encouraged to develop mathematical thinking, mathematical attitude and understanding of mathematical concepts.

**Need of Appropriate Instructional Strategy**

To satisfy the needs of the learners new experiments, creative innovations and appropriate strategies are being developed and tried out to improve mathematics education at all levels. Teachers, as facilitators of a classroom environment where students learn to communicate mathematically and as an agent to improve quality of mathematics lessons, need to employ multiple instructional strategies/techniques such as mathematics laboratory, brainstorming, group discussion, inductive-deductive method, concept mapping, problem solving etc. A strategy that would transform the position of the teacher from being active speaker to facilitator, a strategy that makes the teaching systematic and a strategy that would help the students to master the mathematical concepts easily and may contribute towards the upliftment of mathematics instruction and education is the need of the hour.

**Problem Solving as an Instructional Method**

The last several decades in our nation have witnessed growing concerns that our educational system is not adequately preparing all of our citizens to develop the skills and knowledge they need to live and work successfully in today's complex society. Calls for change have centred on the need for schools to provide opportunities for students to engage in activities that promote in-depth understanding, better acquisition of concepts, critical thinking, creative problem solving and the ability to use knowledge in real-life settings.

In response to these concerns school improvement efforts have proliferated, aimed at all aspects of the educational system present a conception of teaching that focuses on developing thinking and reasoning among students and further on learning skills of problem formulation and solving. This conception is termed as " Problem Solving Instruction " because it sees learning as a dynamic internal process in which learners actively participate by connecting new information to what they already know, rather than as a process in which learners are passive recipients of information transferred to them from external sources. This newer conception's emphasis is on developing students' capacities for analysis and problem-solving, rather than on having them "cover the curriculum" in the most efficient manner possible.

**Meaning of Skill of Problem Solving**

Problem solving is a mental process and is a part of the larger problem process that includes problem finding and problem shaping. Problem solving occurs when an organism needs to move from a given state to a desired future goal state. Farooq (1980) pointed out that a "problem" usually indicates a challenge, the meeting of which requires study and investigation. Skinner (1984) stated that the term "problem-solving" is defined as the frame work or pattern within which creative thinking and learning takes place. It is a process of overcoming difficulties that appear to interfere with the attainment of a goal. Polya (1945) defined problem-solving as the process used to solve a problem that does not have an obvious solution.

According to Heller and Reif (1984), problem solving is an intellectually demanding activity of central importance in any science. All the sciences, both pure and applied, are centrally concerned with developing and systematizing knowledge useful for solving various kinds of problems.

Bay (2000) explained teaching about problem-solving is the teaching of strategies or heuristics in order to solve problems. Kirkley (2003) described problem solving as higher order thinking which includes skills such as visualization, comprehension, manipulation, reasoning, analysis, synthesis and generalization, each needing to be managed and coordinated.

According to Lorain County Community College (2011), problem solving is a tool, a skill and a process. As a tool it helps to solve a problem or achieve a goal, as a skill one can use it repeatedly throughout life and as a process it involves a number of steps.

Thus problem solving is an ability to analyze a situation and then form a workable solution. The problem solving is a process of overcoming difficulties that appear to interfere with the attainment of a goal. It is a systematic way to move from a set of given principles or circumstances to the desired result by using higher cognitive skills like logic, associative reasoning, creative thinking and deductive reasoning.

**Polya's Heuristic Approach to Problem Solving**

George Polya (1887-1985) was a Hungarian mathematician who immigrated to the United States in 1940. His major contribution is for his work in problem solving. He was the first to introduce the concept of problem-solving model.Believing that mathematics is not all about the result, he argued that the essence of mathematics education lies in the thinking and creativity employed in the problem-solving process (Taylor & Taylor, 1993) . He is popularly known as the "*Father of Problem Solving"*(Alexanderson & Pedersen, 1982).

In 1945, Polya published the book "*How To Solve It"* which quickly became his most prized publication. It sold over one million copies and has been translated into 17 languages. In this he identifies four basic principles that uses the 3R's of problem solving i.e. request-response-result and a verification of the result. These are **:**

(a) Understand the problem
(b) Devise a plan
(c) Carry out the plan
(d) Look back.

Each of these steps are considered as separate skills and each step is categorized into sub skills. These separate skills or sub skills are also termed as heuristics or strategies. This four-step process forms the basis of any serious attempt at problem solving and is popularly termed as ***"Polya's Heuristic Approach To Problem Solving".***

**Mathematical Concept Acquisition**

Acquisition of mathematical concepts means the same as achievement in mathematics. It refers to the attainment of certain abilities and development of varied skills during the learning process. Achievement is regarded as the end product of all educational endeavors (Balasubramanayan,1997). It is considered as the sole criteria to evaluate the successful accomplishment of performance in a particular subject, area and course, usually visualized through skills, hard work and interest, typically summarized in various types of grades, marks, scores or descriptive commentary (Hawes & Hawes, 1982). *Here achievement in mathematics and acquisition of mathematical concepts are interchangeable terms and were considered as mean gain scores obtained by the students on mathematical concept acquisition test.*

**Study Habits**

The task of learning is not dependent on teachers' alone. It is not only teachers' responsibility but also of the learners. Efficient learning depends not only on good teaching but also on satisfactory learning procedures. It depends on learner's ability to schedule his time, the plan of his study, the habit of concentration, note taking, mental review, over learning, the judicious application of whole and part methods, massed and distributed learning and so on. In other words learning involves the development of study habits.

Study habits refer to a set of behaviors related to how students organize their time and space to promote systematic study behaviour. It means that the students must be able to organize, classify and arrange facts in their proper relationship to the subject being studied (Sorenson, 1991). Study habits are intended to elicit and guide one's cognitive process during learning (Nuthana & Yenagi, 2009).

Thus , it can be concluded that study habits are true indicators of individuality of a person. These are planned program of subject mastery. They characterize the learner's learning character. In fact, every learner has a peculiar method or style of pursuing his or her academic tasks. Some children like to read alone, some in a group, some read aloud and some silently. There is no strict yardstick to measure the type of study habits.

**Objectives**

1. To investigate the significance of difference in acquisition of mathematical concepts of the groups taught through Problem Solving Instructional Strategy and Traditional Instructional Strategy.
2. To study whether study habits will account for differential acquisition of mathematical concepts.
3. To investigate the significance of interaction between instructional strategies and study habits in terms of student's acquisition of mathematical concepts.

**Hypotheses**

1. There exists no significant difference in the mean scores on the acquisition of mathematical concepts of the groups taught through Problem Solving Instructional Strategy and Traditional Instructional Strategy.

2. There exists no significant difference in the mean scores on acquisition of mathematical concepts of groups having different study habits.
3. There exists no significant interaction between instructional strategies and study habits in terms of student's acquisition of mathematical concepts.

**Sample**

The students studying in Grade IX in different private schools affiliated to PSEB, situated in Moga district of Punjab state formed the target population.In the present study, in order to satisfy the real effort in experimental research, the logical statistical inference of purposive sampling was initially employed to select schools and then random sampling technique was used for the selection of students. The sample in the present study was drawn at two levels such as school sample and the student sample. A sample of 320 students of 9$^{th}$ Grade was selected through the multi-stage sampling technique.

**The School Sample**

For the purpose of the present study only private schools were taken. Although government schools were fulfilling the basic requirements for the present study, yet these schools were not included in the study. The mathematics education and physical facilities in government schools are very pathetic as compared to private schools which are fairly good in terms of mathematics education and physical facilities. Hence, a wide gap in achievement in mathematics of students from government and private schools would have skewed the data. The investigator therefore delimited her study to private schools affiliated to Punjab School Education Board, Mohali. The school sample comprising of ninth grade students was drawn from the representative secondary schools of Moga district of Punjab state. The average age of students ranged from 14-16 years.

- First, five cities were selected by the investigator from Moga district according to her convenience. Then, 10 schools were selected from these five cities by purposive sampling technique. These ten schools represented the population under investigation.
- The principals of all these schools were approached. Principals of all the schools welcomed the idea of teaching the students of ninth grade through problem solving instructional strategy and were willing to participate in the programme. But, then only six schools were drawn from these ten schools by simple random sampling technique.

**Student Sample**

After selecting six schools of Moga district, the students were drawn randomly from the six schools. The investigator picked up 80 students from one school, 80 students from second school, 50 students from third school, 50 students from fourth school, 40 students from fifth school and 80 students from sixth school as presented in table 3.1.

**Table 1 : School-wise Distribution of the Sample (N=380)**

| **S. No.** | **Name of the School** | **Total Students** |
|---|---|---|
| 1 | Summer Fields School, Moga | 80 |
| 2 | D. S. Blossom High School, Moga | 80 |
| 3 | Dasmesh Auckland Grammer School, Dharamkot, Moga | 50 |
| 4 | Navyug Public School, Dharamkot, Moga | 50 |
| 5 | International Public School, Ajitwal, Moga | 40 |
| 6 | S. B. K. S. Senior Secondary School, Charik, Moga | 80 |
| **Total Students** | | **380** |

Table 1 shows that 380 students were selected from six schools of Moga district of Punjab state.

**Sample Distribution**

The sample comprising of 380 students were administered two tests i.e. mathematical concept acquisition test and study habits inventory. Out of 380 students, 10 students did not respond to all the items of mathematical concept acquisition test , 12 students left un-attempted some of the items of study habit inventory and there were 8 students who had not filled up their identifying data properly. Thus total of 30 students were dropped from the sample of 380 students. Hence sample comprising of 350 students were randomly divided into two groups - Experimental and Control. In order to make equivalent groups, matching was done on the basis of pre-test scores. 't'-test was employed to compare mean scores on the variable of mathematical concept acquisition of the group taught through problem solving instructional strategy and traditional instructional strategy. Insignificant 't' ratio showed that both the groups were matched and equivalent.

**Experimental Design**

The present study employed an experimental method with 2X2 factorial design. The study covered two variables viz. Instructional strategy and study habits. The variable of instructional strategy was studied at two levels such as - Problem Solving Instructional Strategy (PSIS) and Traditional Instructional Strategy (TIS). The variable of study habits was studied at two levels i.e high level study habits and low level study habits.

**Tools Used**

1. Mathematical Concept Acquisition Test (MCAT) on selected topics of Mathematics of Grade IX (developed by the investigator).
2. Revised Study Habit Inventory by Mukhopadhyay and Sansanwal (2011).
3. Modules based on Problem Solving Instructional Strategy (PSIS) on selected topics of Mathematics for Grade IX (prepared by the investigator).
4. Lesson Plans based on Traditional Instructional Strategy (TIS) on selected topics of Mathematics for Grade IX (prepared by the investigator).

**Procedure**

The procedure for carrying out the present investigation involved two stages :

- Sample selection and allocation of students into two groups for instructional strategies
- Conducting the experiment

**Sample Selection**

The sample in the present study was drawn at two levels-the school sample and the student sample. The process of sampling has already been discussed in detail under the heading sample for the study and sample distribution.

**Conducting the Experiment**

The experiment was conducted in three phases. The schematic representation of the treatment procedure is given in the table 2.

**Table 2 : Schematic Representation of the Treatment Procedure**

| Phase | Group - $A_1$ | Group - $A_2$ |
|---|---|---|
| **Phase-I (Pre-test)** | Test of Mathematical Concept Acquisition as a Pre-test.<br>Study Habit Inventory | Test of Mathematical Concept Acquisition as a Pre-test.<br>2.Study Habit Inventory |
| **Phase-II (Treatment)** | Exposure through Problem Solving Instructional Strategy. | Exposure through Traditional Instructional Strategy. |
| **Phase-III (Post-test)** | Test of Mathematical Concept Acquisition as a Post-test. | Test of Mathematical Concept Acquisition as a Post-test. |

**Phase-I:** First of all, the investigator made necessary arrangements with the principals of schools selected for the experiment. A mathematical concept acquisition test as a pre-test measure was administered on the total sample. The students were assigned to two groups such as experimental and control group on the basis of pre-test scores to make equivalent groups. Before implementing the problem solving instructional strategy, the two groups were randomly decided and matched on the basis of pre-test scores so that equivalent groups could be formed. The answer sheets were scored to obtain the information regarding the previous knowledge of the students. Secondly the study habit inventory was administered in each school of experimental and control groups. The answer sheets were scored as per the answer key to obtain knowledge about threshold values of learners on the variables.

**Phase-II:** In this phase treatment was given to the experimental group. The experimental group was taught by the problem solving instructional strategy and the control group was taught by traditional instructional strategy by the investigator herself. The duration of instructional treatment was forty sessions in each case with each session of 45 minutes. Regarding the experimental period, the investigator had already contacted with the principals of the schools taken for the study and informed that following topics (portion) of class IX syllabus would be taken by her. The investigator personally requested the concerned subject teachers of the school for leaving the selected portion of class IX from Mathematics syllabus and had taken the time for experimental phase as per their suitability without disturbing their schedules.

Before conducting the experiment, the investigator interacted face to face with each group separately to establish rapport. The purpose of the study was never revealed to the subjects. The students of the experimental group were taught through the modules developed by the investigator. The control group continued with the routine activities and traditional method was used for teaching. No treatment was provided to control group. Students of the control group were not given any information about the strategy.

**Phase-III:** After the completion of the instructional programme, the same mathematical concept acquisition test (MCAT) was administered as post-test to the students of both the groups.The answer sheets were scored with the help of the scoring key. Experimental and control group scores were compared according to their pre-test and post-test scores and difference was called as gain scores of the experimental and control group. The duration of the experiment was three months from mid-July to mid-October.

**Statistical Techniques**

1. Descriptive statistics viz., mean, standard deviation, skewness and kurtosis were computed on the total sample to ascertain the nature of distribution of scores.
2. Analysis of variance employing 2×2 factorial design was computed for mean gain scores to study the main and interaction effects.
3. For the significant F-ratio, t-test was employed to find out the significance of difference between means related to different groups and variables.

**Analysis And Interpretation**

**2x2 Analysis of Variance Related with Gain Scores**

Before applying 2x2 analysis of variance, the assumptions underlying ANOVA were tested.

***Normality of Distribution:*** The first assumption that observations in experimentally homogeneous sets should be from normally distributed population was tested through descriptive statistics. From the descriptive statistics, the distribution can be taken as near normal.

***Randomness:*** The second assumption of assigning mutually exclusive cases to each sets of 2x2 factorial design of ANOVA was satisfied by randomly assigning students to different treatment groups.

***Homogeneity of Variance:*** The third assumption of homogeneity of variance in the groups stating that the variance of scores in each of the treatment groups should be homogeneous, that is, the variances of the individual groups should be equal were tested by applying Levene's Test of Homogeneity of Variance as given below in table 3.

Table 3 reveals that the value of Levene's statistic for test of homogeneity of variance is 1.334 which is non-significant at 0.01 level with degree of freedom 15/160. It indicates that there is no variance. Thus it tests the null hypothesis that the error variance of the dependent variable (mathematical concept acquisition) is equal across groups. Hence, the variance within the cells can be treated as homogeneous.

**Table 3 : Levene's Test of Homogeneity of Variance**

| $df_1$ | $df_2$ | F-statistic | p-value |
|---|---|---|---|
| 15 | 160 | 1.334 | .187* |

**insignificant (significance defined as p < .01)*

***The Contribution of Total Variance is Additive:*** This assumption of additivity of variance was satisfied through the procedural operations of calculations.

After satisfying the basic assumptions underlying ANOVA, the calculation of 2x2 analysis of variance was carried out by the investigator. 2x2 ANOVA was computed on gain scores on the variable of acquisition of mathematical concepts by varying the treatment variables of instructional strategy and study habits. Instructional strategy (A) was varied in two ways: PSIS formed group (A1) and TIS formed group (A2) and study habits in two ways: high level study habits formed group (B1) and low level study habits formed group (B2).

**2x2 analysis of variance related with gain scores on the variable of mathematical concept acquisition in relation to instructional strategy and study habits**

In this section F-values were calculated to study the main and interactional effects of two factors viz: instructional strategies and study habits with regard to gain scores on the variable of mathematical concept acquisition. The F-values were calculated by using two way ANOVA test. The 't'-test was also employed in case of significant F-value.

The mean, sum of squares, degree of freedom, mean sum of squares and F-ratios have been worked out for different sub-groups and the same have been presented in table 4.

**Table 4 : A Summary of 2x2 (Two-way) ANOVA Factorial Design**

| Dependent Variable | Source of Variation | Sum of Squares | Degree of Freedom | Mean Sum of Squares | F-statistic | p-value |
|---|---|---|---|---|---|---|
| **Mathematical Concept Acquisition** | **Instructional Strategy (A)** | 1303.642 | 1 | 1303.642 | 284.666** | .00 |
| | **Study Habits (B)** | .960 | 1 | .960 | .210 | .648 |
| | **AxB** | 9.381 | 3 | 3.127 | .683 | .564 |
| | **Error Term** | 732.727 | 160 | 4.580 | | |
| | **Total** | 15865.00 | 176 | | | |

** Significant at 0.05 level (significance defined as p < .05)*
*** Significant at 0.01 level (significance defined as p < .01)*

Table 4 shows 2x2 ANOVA related with gain scores on the variable of mathematical concept acquisition in relation to instructional strategy and study habits.

**Interpretation**

**Main Effects**

- Effect of instructional strategy on acquisition of mathematical concepts
- Effect of study habits on acquisition of mathematical concepts

The above said main effects of independent variables on dependent variable were carried out to achieve the following objectives of the present study:

**First Objective:** To investigate the significance of difference in acquisition of mathematical concepts of the groups taught through problem solving instructional strategy and traditional instructional strategy.

**Second Objective:** To study whether study habits will account for differential acquisition of mathematical concepts.

**Effect of Instructional Strategy (A)**

The results presented in table 4 reveals that F-statistic corresponding to instructional strategies is 284.666, which is highly significant ($p < .01$) at 0.01 level of significance. Therefore, the null hypothesis $H_0 1$ stating, "There exists no significant difference in the mean gain scores on the acquisition of mathematical concepts of the groups taught through problem solving instructional strategy and traditional instructional strategy" stands rejected at specified level.

In order to probe deeper, F-statistic was followed by t-test. The significance of difference between mean gain scores of experimental and control group has been presented in table 5.

**Table 5: Significance of Difference Between Mean Gain Scores of Experimental and Control group**

| **Group** | **Gain Scores** | | | | |
|---|---|---|---|---|---|
| | **N** | **M** | **SD** | **$SE_D$** | **t-value** |
| **Experimental Group** | 160 | 11.06 | 2.227 | .234 | 22.08* |
| **Control Group** | 160 | 5.89 | 1.952 | | |

**significant at 0.01 level of significance*

*$t_{(table)}$ is 1.96 at 0.05 level and 2.58 at 0.01 level of significance, df = 318*

A bar diagram has been drawn to depict the mean gain scores on achievement in mathematics and has been presented in fig.1.

Table 5 and fig. 1 indicate that the mean gain scores on achievement in mathematics of experimental group is 11.06 which is higher than the corresponding mean gain scores of 5.89 for the control group. The t-value testing the significance of mean gain difference on achievement in mathematics of two groups is 22.08 which in comparison to the table value was found to be significant at 0.01 level of significance. It means that both the groups were significantly different on the mean gain scores on the variable of acquisition of mathematical concepts. It may be concluded that imparting instruction through PSIS resulted in significant difference in mean gain achievement scores than those imparted through TIS.

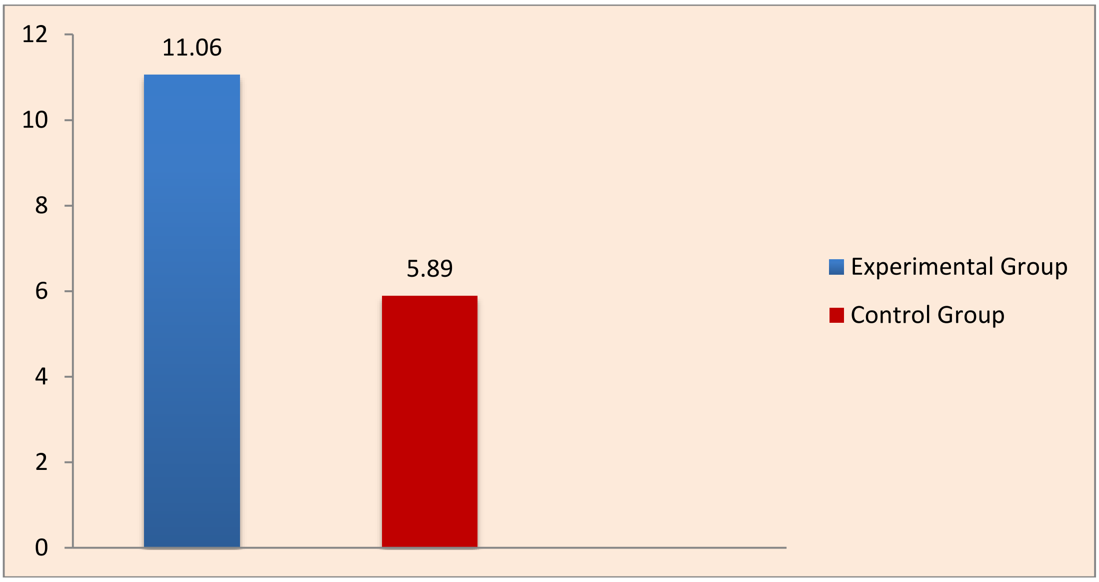


**Fig.1: Bar Diagram Showing Comparison of Mean Gain Scores of Experimental and Control Group**

**Effect of Study Habits (B)**

It may be observed from the table 4 that the F-statistic corresponding to study habits is .210, which is insignificant at both levels of significance (0.05 & 0.01) as p = .648 which is greater than both 0.01 & 0.05.. This indicates that the high level study habits group and low level study habits group were equal on mean gain achievement scores. It means that both the groups were not significantly different on the variable of mathematical concept acquisition. Hence the null hypothesis $H_03$, "There exists no significant difference in the mean scores on of groups having different study habits" stands accepted at specified level of significance.

**Interactional Effects**

First order interactions were carried out between independent variables viz. instructional strategy and study habits and dependent variable of acquisition of mathematical concepts.The interactional effect of instructional strategy and study habits on acquisition of mathematical conceptswas carried out to achieve the following objective of the present study:

**Third Objective:** To investigate the significance of interaction between instructional strategies and study habits in terms of student's acquisition of mathematical concepts.

**Interactional Effect of Instructional Strategy and Study Habits (AxB)**

Table 4 depicts F-statistic as 8.964 for interaction between instructional strategy and study habits, which is significant ($p < .01$) at 0.01 level of significance. This revealed that that the interactional effect on achievement in mathematics was signified at the

specified level. It may be concluded that there was a significant difference in the mean gain achievement scores due to interaction between instructional strategy and study habits. Hence the null hypothesis $H_0$5, "There exists no significant interaction between instructional strategies and study habits in terms of student's acquisition of mathematical concepts" stands rejected.
To ascertain significance of difference among means of different combination groups, t-ratios were computed, which have been placed in table 6.

**Table 6: t-ratio's for Different Combinations of Instructional Strategy and Study Habits**

| **Instructional Strategy →** | **Experimental Group (A1)** | | | | | | **Control Group (A2)** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Study Habits →** | **B1** | | | **B2** | | | **B1** | | | **B2** | | |
| **Combination Pairs ↓** | **N** | **M** | **SD** | **N** | **M** | **SD** | **N** | **M** | **SD** | **N** | **M** | **SD** |
| | 44 | 12.09 | 2.250 | 44 | 10.98 | 2.308 | 44 | 5.68 | 2.513 | 44 | 6.50 | 1.759 |
| **A1B1** | - | | | 2.292* | | | 12.604** | | | 12.987** | | |
| **A1B2** | - | | | - | | | 10.296** | | | 10.236** | | |
| **A2B1** | - | | | - | | | - | | | 1.769 | | |
| **A2B2** | - | | | - | | | - | | | - | | |

**Significant at 0.05 level* ***Significant at 0.01 level*
*$t_{(table)}$ (df=86) at 0.05 and at 0.01 level of significance is 1.99 and 2.63 respectively.*
*Note: Here A1stands for experimental group and A2 stands for control group.*
*B1 stands for high level study habits and B2 stands for low level study habits.*

Bar diagram was drawn to substantiate the results and has been placed in fig.2.

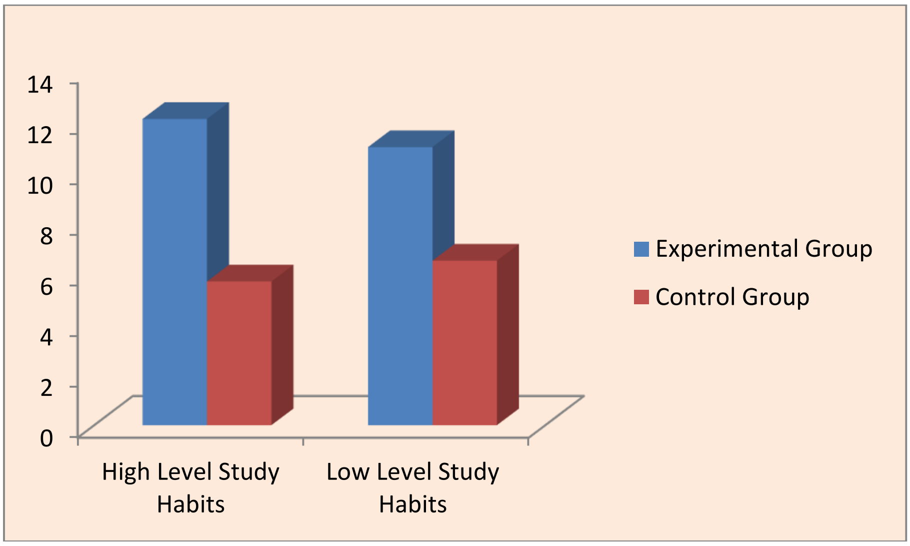


**Fig. 2: Bar Diagram Showing Comparison of Mean Gain Sores of Instructional Strategy and Different Study Habits**

It is depicted from the table 6 and fig. 2 that:

- The mean gain achievement score of students of the experimental group having high level study habits were found to be 12.09 which is higher than the corresponding mean gain score of 10.98 of students of low level study habit group. The t-ratio for difference in mean gain scores of high level study habit group and low level study habit group of the treatment group is 2.292, which in comparison to the table value was found to be significant at 0.05 level of significance. Hence it may be inferred that students of the experimental group having high level study habits exhibited greater mean gain scores than the low level study habit group.
- The mean gain achievement scores of the students having high level study habits belonging to experimental group were found to be 12.09 which is higher than the corresponding mean gain score of 5.68 for control group with high level study habits. The t-ratio for difference in mean gain scores of high level study habit students of treatment group and high level study habit students of the control group is 12.604, which in comparison to the table value was found to be significant at 0.01 level of significance. Hence it may be inferred that students of the experimental group having high level study habits exhibited greater mean gain scores than the high level study habit students of the control group.
- The mean gain scores on achievement of the experimental group with high level study habits were found to be 12.09 which is higher than the corresponding mean gain score of 6.50 for control group with low level study habits. The t-ratio for difference in mean gain scores of high level study habit students of experimental group and low level study habit students of the control group is 12.987, which in comparison to the table value was found to be significant at 0.01 level of significance. Hence it may be inferred that students of the experimental group having high level study habits exhibited greater mean gain scores than the low level study habit group of the control group.
- The mean gain achievement scores of the experimental group with low level study habits were found to be 10.98 which is higher than the corresponding mean gain score of 5.68 for control group with high level study habits. The t-ratio for difference in mean gain scores of low level study habit students of treatment group and high level study habit students of the control group is 10.296, which in comparison to the table value was found to be significant at 0.01 level of significance. Hence it may be inferred that students of the experimental group having low level study habits exhibited greater mean gain scores than the students of the control group having high level study habits.
- The mean gain scores on achievement of the experimental group with low level study habits were found to be 10.98 which is higher than the corresponding mean gain score of 6.50 for control group with low level study habits. The t-ratio for difference in mean gain scores of low level study habit students of the treatment group and low level study habit students of the control group is 10.236, which in comparison to the table value was found to be significant at 0.01 level of significance. Hence it may be inferred that students having low level study habits of the experimental group exhibited greater mean gain scores than the low level study habit students of the control group.
- The mean gain scores on achievement of the control group with high level study habits were found to be 5.68 which is lower than the corresponding mean gain score of 6.50 for control group with low level study habits. The t-ratio for difference in mean gain

scores of high level and low study habit students' of the control group is 1.769 , which is insignificant at 0.05 level of significance. Hence it may be inferred that students having low level study habits of the control group exhibited greater mean gain scores than the high level study habit students of the control group. It leads to the conclusion that students of control group having high level study habits and low level study habits achieved equal mean gain score on the variable of acquisition of mathematical concepts. No doubt the mean gain score of the group of students of low level study habits is higher as compared to those with high level study habits by the difference of 0.82. But as the difference is statistically insignificant, hence, it is concluded that there is no significant difference.

**Findings And Conclusions**

1. Main effect of instructional strategy (F-ratio=284.666) on the variable of acquisition of mathematical concepts of the groups taught through PSIS and TIS is significant at 0.01 level of confidence. There was significant difference in the means of the two groups {M (PSIS)=11.06} and {M(TIS)=5.89} and the mean gain is in favour of group taught through PSIS. Thus it can be concluded that students taught through PSIS were found to achieve significantly high on the acquisition of mathematical concepts than taught through TIS. Thus PSIS proved to be a better instructional strategy over TIS.
2. Main effect of study habits (F-statistic = 0.210) on the variable of acquisition of mathematical concepts of the group of students with high level study habits and group of students with low level study habits is insignificant. There was no significant difference in the means of the groups with high level study habits (M=8.89) and low level study habits (M=8.74) on the variable of acquisition of mathematical concepts. Thus it can be concluded that no significant main effect of study habits is found on mathematical concept acquisition. Students having high level study habits achieved equal to the students having low level study habits. Thus study habits proved as a redundant factor so far as acquisition of mathematical concepts is concerned.
3. Interactional effects of instructional strategies and study habits (F-statistic = 8.964) on the variable of acquisition of mathematical concepts were found to be significant at 0.01 level of significance. Different groups for two types of instructional strategies and two levels of study habits showed different and significant mean gain score on the variable of acquisition of mathematical concepts.Thus it can be concluded that the significant interactional effect of instructional strategies and study habits is found on acquisition of mathematical concepts. Students belonging to both high and low level of study habits achieve higher when taught by PSIS as compared to those taught by TIS.

**Implications**

The findings of the present study revealed that heuristic approach to problem solving is an instructional strategy leading to better concept acquisition of students in mathematics. Students showed positive response towards mathematics when taught through problem solving instructional strategy. Moreover, problem solving instructional strategy geared towards students' needs, interest and capabilities. Thus the study has implications for the students, teachers, teacher-educators, administrators, parents and society.

- **Students**

- On the basis of the findings of the study, it is strongly recommended that PSIS should be used to enhance quality of education at school level and even at college level. As we all know that the performance of the students in mathematics is not at all satisfactory at every level of education. This is due to the reason that students lack conceptual understanding of the subject and they are also poor in higher order thinking skills. Much has been written about the ways of improving mathematical concepts of the students. But , efforts made in reality are far from satisfactory. The results of the present study showed that PSIS modules enhanced the concept acquisition of students in mathematics. Polya's method centered around 'doing' mathematics with great emphasis on teaching students how to think mathematically, it arouses and sustain their interest in mathematics. The use of different heuristics, principles and self-directed questions (suggested by Polya) helped the students to explore their innate intellectual abilities. Moreover, the stage-wise problem solving helped the students to become familiar with the problem- solving process which thereby leads to better acquisition of mathematical concepts.
- In addition to this, positive learning effects happen when students work with PSIS, they also develop many new skills and mental capabilities such as problem solving skills, analytical skills, creativity, logical thinking and reasoning, reflective thinking, devising and implementing various plans and procedures, systematic examination of facts and making inferences and drawing conclusions etc. These skills cannot be developed in traditional classroom teaching. Thus, to cope up with the requirements of development of mathematical and higher order thinking skills needed for 21$^{st}$ century, teachers should be encouraged to make maximum use of PSIS in their teaching learning process.

  Therefore students should be taught mathematics with the help of this method and mathematics pupil teachers should be trained for using Polya's problem solving approach. Thus the present investigation will help the students in the following ways:

- ✓ Explaining Polya's four principles of problem solving.
- ✓ Enlisting the various problem solving strategies and heuristics for solving different problems and further selecting a particular strategy to tackle a problem.
- ✓ Apply a variety of appropriate heuristic questions to solve problems.
- ✓ Developing concept clarity and thereby leading to better understanding of the subject matter.
- ✓ Enhancing interest in learning mathematics by active participation and at their own pace.
- ✓ Boosting confidence by improving their conceptual clarity and using mathematics meaningfully.
- ✓ Monitor and reflect on the process of mathematical problem solving.
- ✓ Build new mathematical knowledge and concepts through problem solving and helping them in formulating generalisations.
- ✓ Discouraging the concept of rote memorisation in learning of mathematics that will help in retaining the content for a longer period of time.

- **Teachers**
  - As a mathematics teacher the prime interest should be in problem solving rather than stubbornly insisting on the single right approach. The present study provides an exemplary work of understanding and solving the mathematical problems. The study can be very helpful for mathematics teachers to guide and enable to carrying out problem solving task with their students to improve their mathematical understanding.
  - PSIS is an effective teaching strategy that is found to be helpful in enhancing the level of learner's performance in mathematics with different study habits and learning styles. The experiment at private schools with limited resources gave the results in terms of enhancing learning through PSIS. Hence adequate amount of planning and participation by creative teachers with flexible attitude in classroom transaction can lead to enhancement of mathematical concept acquisition.
  - A teacher should always be on a learning curve. He has to refresh and reframe his knowledge and skills continuously. This is even more essential in case of teachers of specialized subjects like mathematics. Keeping this in view, extensive training programmes, workshops and seminars have been organized for in-service mathematics teachers under various schemes like SSA, RMSA etc. Seminars and in-service programmes should also be organized by all mathematics associations and clubs, examination boards, delegates of education and the pedagogic offices for teachers in the field to be acquainted with new and innovative techniques and methods of teaching. The findings of the present study recommend that in those workshops/seminars, mathematics teachers must be acquainted with Polya's heuristic approach to problem solving so that they can employ this method in the classrooms.
  - Psychological incentives in form of recognition, job autonomy, independence and higher responsibilities can be offered to teachers who develop and use PSIS based instructional material (modules) in their teaching learning process and in turn facilitate mathematics learning.
- **Teacher Educators**

  Teacher education programme is a medium through which education of a nation propagate. It must be in tune with the recent researches and developments in the field of education. Mathematics is not taught in the way it should be taught, as prescribed activities in the textbooks are not practiced. Inclusion of PSIS in B.Ed curriculum would abreast pre-service teachers with the superior and innovative ways of enhancing mathematics achievement of the students.
- **Administrators**

  The findings of the study indicate that Polya's PSIS has to be applied into the classrooms. It implies that the Polya's approach needs support and encouragement of the administrators vis-a-vis training requirements of teachers, flexibility in time-table etc. Thus the support of forward looking school administrators can change classroom environments for better mathematics learning.
- **Government**
  - Problem solving should be incorporated into the curriculum in all institutions including teacher training colleges and faculties of education in all universities. The present study supports that the strategy of problem solving can be introduced by the government in

the theory classes not only at the secondary level but also right from the primary level to the college level and even at the university level.

- Government should transform the textbooks of mathematics in problem based learning form. The traditional textbooks do not meet the criteria of problem solving approach. Authors and textbook writers should apply and provide proper illustration of Polya's problem solving strategies and heuristics in different branches of mathematics. This may enable the students to generate their own algorithms, heuristics and strategies and generalize it into specific set of applications in mathematics.

❖ **Parents**

Parents of the present day are very much concerned about the studies of their wards. Parents try to provide every facility to their children so that they are able to excel academically. But parents are not aware of the various researches and developments going on in the field of mathematics education. The study has implications for parents that they must go through the Polya's approach and apply this model while teaching mathematics to their children.

To conclude, it is suggested that teachers and students should learn to apply the psychological view of Polya's model in problem solving because it consists of finding the right steps to apply at the right time or the creation/ invention of new ways to convert one state of a task into another. In other words, Polya's problem solving involves the representation of the problem situation and the application of principles in order to generate a solution. The study thus recommends the cyclic and the scientific approach to problem solving because it motivate the learners and develop the spirit of exploration and discovery.

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