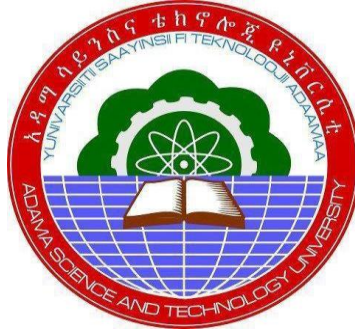


STRATEGIES IN SOLVING MATHEMATICAL PHYSICAL PROBLEMS AND THEIR ROLES IN EFFECTIVE TEACHING OF PHYSICS IN ETHIOPIA, (A CASE OF PREPARATORY SCHOOL IN ADDIS ABABA).

**BY;- Abdu Negash Nuru**



**A THESIS SUBMITTED TO  
THE DEPARTMENT OF APPLIED PHYSICS,  
SCHOOL OF APPLIED NATURAL SCIENCE,  
PRESENTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT  
FOR THE DEGREE OF MASTERS OF SCIENCE IN PHYSICS.**

**OFFICE OF GRADUATE STUDIES  
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**Advisor:-Alemu Kebede(PhD)**



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**August, 2017**

## **Declaration**

I hereby declare that this MSc thesis is my original work and has not been presented for a degree in any other university, and all source of material used for the thesis/declaration have been duly acknowledged..

Name Abdu Negash

Signature \_\_\_\_\_

This MSc thesis has been submitted for examination with my approval as

Thesis advisor

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Date of Submission.....

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

GRADUATE STUDIES PROGRAM

BOARD OF EXAMINERS' APPROVAL SHEET

As members of the board of examiners for the Degree of Masters of Science in Physics, Thesis Open Defense Examination of Abdu Negash, I certify that I have read and evaluated his thesis entitled "Strategies for Solving Physical Mathematical Problems and Their Roles in Effective Teaching of Physics in Ethiopia (A case preparatory School in Addis Ababa)" and examined the candidate. I therefore, recommend that the thesis could be accepted as it fulfills the requirements for Degree of Masters of Science in Physics.

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SGS approval	Signature	Date

## *DEDICATION*

*This work is dedicated to the late Hassen Salih Ahmed , his new coming daughter Fatimatizahra Hassen Salih and his unforgettable sister the late Amina Salih Ahmed.*

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## Acronyms

**PER** – Physics Education Research

**ELIP** – English Language Improvement Program

**SG** – Strategy Group Students

**CG** – Controlled Group Students

**PAT** – Physics Achievement Test

**PSPT** – Problem Solving Performance Test

**PSSS** – Problem solving Strategy Scale

**PSCT** – Problem Solving Precondition Test

**PSRT** – Problem Solving Revision Test

**SD** – Standard Deviation

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## ***Abstract***

*The thesis presents problem solving strategies aimed at addressing major problems in learning and teaching physics. Physics problem solving strategy is a best tool in teaching of the subject and in making students understand the concept of what they are taught. In this regard this thesis includes physics problems solving strategies implemented in different preparatory schools on selected groups of students. The target of the study is to introduce the contents problem solving strategy in physical mathematical problems and its role on deep understanding of physics concept. Then forty eight Natural science students were purposively selected from each natural science section and taught in extra classes. In addition to this questioners were distributed to check prior awareness of teachers and students on the strategy and also student's physics text books are analyzed using statistical tools like frequency, standard deviation and mean value of Pre and post intervention test results recorded to show their improvement. According to the finding of this research it is possible to conclude that implementation of the five steps of the strategies: that is, understanding the problem, describing the physics, planning the solution, carrying out the plan and checking the solution, is the best tool to improve student's conceptual understanding. Investigations of students' text books and questioners distributed for teachers and students indicated that physics teaching system is in lack of these important five step strategies.*

# Chapter One

## Introduction

### 1.1. Back Ground of the study

One of the most important concerns of the modern education is to educate individuals who are trying to overcome the problems which they encountered in their daily and social lives. This means problem solving will be the goal of modern education. Problem solving is usually defined as formulating new answers going beyond the simple application of previously learned rules to create a solution [1]. Mathematical problem solving can also be taken /Considered/ from this point of view. Mathematical problem solving plays a central role in instruction of physics as well as all other sciences. All the sciences, pure and applied, are centrally concerned with developing and systematizing knowledge useful for solving various kinds of problems. This is process of teaching student to become more proficient problem solvers. The new generation at large needs large number of science student's population because of significant changes in the environment of society over the large several decades. The change in the environment and social conditions of society comes up with various problems to be solved by the generations and without modern education this cannot be expected. Modern education requires effective teaching techniques and strategies which is accompanied by mathematical problems solving strategies which needs better and effective methods of teaching to achieve the objective.

Student understanding of theoretical facts of the subject has to be supported by mathematical skills. In spite of this fact, traditional physics instruction which is used in almost all Ethiopian schools has been the main reason for the short comings observed in conceptual understanding of physics. In this techniques most of the class time (the process of instruction) involves the teacher presenting his lesson while the students are simply listening. When mathematical problems are to be solved, the teacher or the students, (if chance is given) use as much as possible a very short method in which the problem is not read, but given and required quantities are collected and written in symbols. Sometimes the students may not even know what quantity the symbols stands for. Then the memorized formula and simple algebraic rules will be integrated to solve the problem. There is no discussion on the real physical meaning of the problem. As an illustration

of what is mentioned above let's see one common example solved in Ethiopian preparatory schools as an introduction to Newton's 2<sup>nd</sup> law (basic law of dynamics). The problem is written as follows:

A block of mass 2kg was acted by force in its direction of motion so that it accelerates at  $3\text{m/s}^2$  in the same direction. What will be magnitude and direction of the force acted on it?. (One can see that the problems is clear and open for discussion). Instead what was done by the teacher or the students to solve this problem was:

<u>Given</u>	<u>Required</u>	<u>Solution</u>
$m=2\text{kg}$	$F=?$	$F= ma$
$a= 3\text{m/s}^2$		$= 2\text{kg} \times 3\text{m/s}^2$
		$\Rightarrow \underline{F= 6\text{N}}$

When we refer to the solution and the steps it could, algebraically, be correct, but from physics point of view, it does not have any contribution to the student's understanding of the subject. That is, it doesn't involve a step which explains the physical meaning of the problem, why the formula is applied and way of checking the correctness of the solution. This might have been the main cause for failure of instruction in Ethiopia and other countries. The failure forced researchers to investigate better methods of teaching. Much of recent researches like by physics education research (PER) favors an over emphasis on qualitative (conceptual) physics aspects. The field of physics education research has seen in considerable growth over the last decades. Its practitioners have amassed a convincing array of evidences that traditional physics instruction emphasizing on derivation and numerical problem solving only is, rather inefficient in achieving desired objective [1]. In other words it is of particular concern considering the intrinsically quantitative nature of physics in physics classes. Students should actually be trained in their mathematics classes and the aforementioned opinions might be a result of the fact that many of the published papers in teaching and learning physics to over emphasize the importance of teaching conceptual physical aspects and to deemphasize the significance of standard mathematical reasoning which are crucial for understanding physical process. Unfortunately since the traditional method of instruction is predominantly being applied over Ethiopian Secondary schools, students joining higher educations, finishing their secondary school lesson,

are not equipped with sufficient physics knowledge. Sometimes the shortage is so serious that they cannot be able to continue the lesson of the next level. Let's see samples of occasions faced in my experiences in teaching physics. Once when I was teaching a lesson in kinematics, we have already covered lesson of acceleration and now ready to convert the idea in to concept of acceleration due to gravity. The formula was written accordingly to apply it in vertical up ward motion as  $V = V_0 - gt$ , and I was expecting that everybody knows what the formula means. Then I asked a question, "taking  $g = 10\text{m/s}^2$ , what will be velocity of a ball thrown up at speed of  $40\text{m/s}$  at the end of two seconds?" every student was running to write "given" required "solution", then formula etc. .... This is due to lack of knowledge of interpretation of the formula as they were taught only to substitute values in the formula. That is, the role of every quantity in the formula will not be explained in traditional instruction. There are number of teachers who suffer from the same problem as they are also from the same source.

The other case is a better surprising that it refers to teachers instead of students. .While I was teaching in one of Addis Ababa high schools, an ELIP (English language improvement program) was designed for all teachers and I was one of the participants. One session of the ELIP was experience sharing practice in which, turn by turn, the participants teach one lesson from their own subject even though participants were from different fields. During my turn I selected Newton's 1<sup>st</sup> law as a title and explained for about 10 minutes. Finally I asked question "A constant force  $F$  is exerted on an object at rest so that its velocity increases uniformly to  $8\text{m/s}$ . Then an equal and opposite force is applied to the object just up on arrival of the velocity of  $8\text{m/s}$ . What will be the next motion of the object"?

From about 40 participants five were physics teachers at different high school and my concern was on their answer. One of them answered that it stops rapidly while the answer of the remaining four is "It comes to gradual stop". This answer was given by physics teachers in capital of the country. So we have to wake up towards a change. The way we give lesson affects the magnitude of the message transmitted to the learners. Therefore in order to achieve a desired goal methods of instruction must responsibly be selected. Specially, in physics, making problem solving a necessary tool for conceptual understanding is necessary. Problem solving can and should remain central to instruction of all sciences, but how it is practiced must change as part of a fundamental rethinking of instructional process. Results from physics education research have

illustrated the nature of expertise and cognitive process required to achieve it. This includes conceptually designed problem solving activity [2]. Through conceptual problem solving strategies students and instructors can achieve a better performance in process of teaching & learning physics. On the instructor side the need for a systematic approach on the teaching of physics could be justified by the advantage of using methodology which help them to incorporate both conceptual & mathematical reasoning systematically in the teaching. In this way students will obtain the necessary training in their computational skill - while learning how to use mathematical skill to obtain physics in the equation, even when they can obtain the mathematical solution to problem by rote procedures. In other words students could apply higher order thinking skills via the mathematical understanding of a physics problem which in turn involves meaningful learning which goes beyond the mere application of rote procedures [3]. More over using properly designed quantitative problems that require students to illustrate their conceptual learning & understanding will reveal much to instructors about their students learning & will provide invaluable feedback. Such problems can also be a powerful way to help students to understand the concepts of physics.

On the students side, the need for the systematic approach in the learning could be justified by the usefulness of applying a working methodology which could help them to approach the learning of physics from inter related point of view. That means that their knowledge of mathematics is useful for mastering ideas from physics & that the use of analogies are important in approaching of physics, mathematical & engineering problems [3]. Two factors can help make you a better physics problem solver. First of all one must know & understand the principles of physics. Secondly one must have strategy of applying these principles to new situation in which physics can be help full. Many students say "I understand the material I, just can't do the problem" "If this is true of you as a physics student, then maybe you need to develop your problem solving skill having a strategy to organize those skills can help you[3].

## **1.2 Statement of the Problem**

Students at high schools struggle with difficulties during solving quantitative physics tasks. The main cause for these obstacles is the lack of suitable methods & strategies for solving physics problems. This is one of the most continual problems in learning physics. Most topics in physics such as mechanics, optics, electricity & several others involve problems which can be solved simply & effectively using proper strategy. In absence of the proper strategy instruction of physics develops high negative impression that physics is too difficult & as such few students are pursuing it at various levels of academies discipline [4]. More students joined the stream completed their education without having necessary knowledge of not only the subject matter but also even ordinary mathematical problem solving skill. It is mentioned above that physics is perceived to be difficult due to lack of proper problem solving strategy. Specifically most of the candidates had problems in:

- i) Data analysis in terms of drawing graphs to illustrate given physical phenomena
- ii) Definitions & explanation of physics concepts
- iii) Not be able to distinguish between the situation in which certain phenomena occur & the use of such phenomena.
- iv) Failure to read the questions very well before attempting to answer it.
- v) Run to substitute numerical values too early before arrangement of the necessary equations and.
- vi) Weak mathematical back ground.

The above mentioned observation concerning the study of physics have motivated the researcher to introduce a strategy that could help to improve student's problem solving skill.

## **1.3 Basic Question of the problem**

In almost all Ethiopian preparatory schools physics instruction methodology has to be improved. The improvement requires series of researches carried out in the area. Any work towards this problem must answer questions that targets the existing problems. Accordingly, this study is designed to give answer for the following questions.

1. What are the limitations of traditional methods of instruction towards conceptual understanding of the students?
2. What strategies are suitable to improve student's skill in problem solving?
3. Will the strategies develop ability of the students to understand the concept of what they are learning?
4. Will this strategy change student's interest towards the subject?

## **1.4 Objectives**

### **1.4.1 General Objectives**

The general objective of the study is to find the significance of problem solving strategy in physical mathematical problems that are familiar to high school teacher and students.

### **1.4.2. Specific Objectives**

- To find the short comings in traditional way of solving problems.
- To introduce the concept of strategies of solving mathematical problems.
- To indicate the extent of advantage by applying the strategies over the traditional method

## **1.5. Significance**

The study is so significant that it enables both teachers and students as well as curriculum expert so that they will have a path way to promote the present curriculum and school atmosphere towards the medium of providing and obtaining a complete and fruitful knowledge in physics. In addition to this, the study helps to understand that strategically guided problem solving is one of the ways of teaching the theoretical concepts of physics.

## **16. Limitations**

The traditional problem solving method are very short and fast when they are compared to the application of the new strategies. Because they involve simple derivation or memory of formula and substitution of numerical values followed by simple mathematical operation. But the strategy requires several steps supported by statements of explanation in each category. Therefore it takes relatively larger time even though the advantage is preferable than its limitation. There are no. of strategies introduced for physics improvement of physics instruction, like:

1. Preparation of alternative problems
2. Group problem solving
3. Knowledge organization
4. Meta cognitive strategy
5. Multiple perspective [5]

Since they all refer to specific activities, they are not taken as part of this study. Instead the general strategy which can replace the above strategies is considered. Since the study is designed to mathematical problem solving strategy, other alternative instructional methods and concept attainment processes were not discussed.

## **1.7 Definition of terms**

The terms used in this study are considered to have the following meanings

1. Well defined problems,- problems whose solutions are straight forward and easily arrived
2. Ill-defined problems,- complicated problems whose solutions cannot be found by direct application of given values
3. Expertise - a person or group of individuals trained in the area of consideration
4. Novies – students(trainees) of a given field
5. Controlled group students - Students selected for study but trained in normal class system
6. Strategy group students – students selected for study and thought by strategic approach

# CHAPTER TWO

## 2. Literature review

### 2.1 What is problem solving?

There are large number of definitions, explanation and comments given on problem and problem solving. In the following few pages I will mention some of the suggestions given by different individuals. According to Newell “a person is confronted with a problem when he wants something of action he can perform to get it. Similarly Simply Martinez states problem solving as a process of moving towards its goals when the path to the goal is uncertain[6].

Another definition is by the mathematician Royal, he defines problems solving as “Search for some action appropriate to attain clearly conceived aim”. Some of written literature on problem solving states that the basic components of problems are considered to be information provided or an initial state (given), the desired end state (required) and means to get from the initial state goal (operation). In addition to this one problem can be different from the other vastly, however in their structure they are well defined and ill-defined problems to mean clear starting point and closed information respectively.

One of the most important target of the modern education is to educate individuals who are over coming problems which they are encountered in their daily lives. Serway and Beichner strongly advise that developing the skills which are necessary to solve a wide range of problem is keeping one self with the statement “you don’t know anything until you have practiced. They express that problem solving ability would be one of the main tests of knowledge of physics and they advise trying to solve as many problems as possible. In clear and simple description, Problem solving is usually defined as formulating new answer going beyond the simple application of previously learned rules to create a solution. It is an investigative task where by the solver explores the solution path to reach from a given information. It is known that all the sciences, pure and applied, are centrally concerned with developing and systematizing knowledge useful for solving various kinds of problems the basic problem solving process is a lined hierarchical process in which each step is the result of previous step and persecutory to the next step which carry the meaning of physical phenomena of the problem through mathematical operation in case of mathematical problem solving process. This shows that solving physics problem is not

different from solving any kind of problem [6]. In short problem solving is finding path way to unknown phenomena using scientifically approved steps.

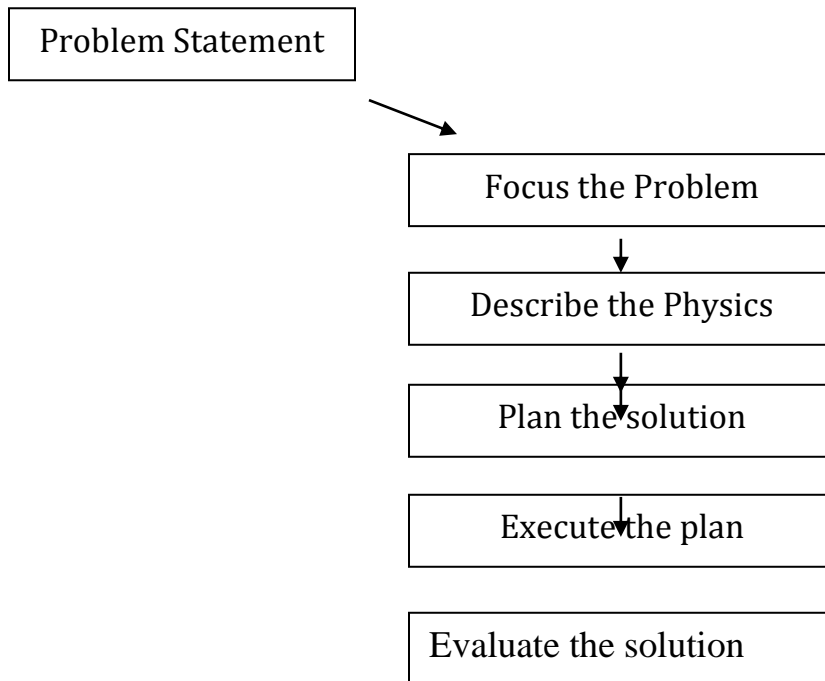
## **2.2 Problem solving strategies**

In order to achieve the desired objectives of physics instruction it will be necessary to be familiar, as much as possible, with selected strategies which can make problem solving means for understanding concept of physics. Numerous problem solving medals have been proposed which can be applied in a variety of disciplines like physics, medical diagnosis, engineering, computer programming etc. There are many similarities in the way expertise in their disciplines solve problems. According to different recent articles printed on physics problem solving, there are five strategies on this discipline. They are alternative problems, group problem solving, knowledge organization, metacognitive strategy and multiple perspective strategy. All the above refer to particular activity and can more or less be categorized under the general strategy. That is, the most important result is that experts follow general strategy for solving all complex problems. This general strategy involves five steps as described below.

1. Comprehend the problem- visualizing the situation, identifying the actual problem and identifying information relevant to the problem.
2. Describe the discipline: - Representing the problem in the formal term relating the concept of the discipline using the accurate concept of the field. This enables to simplify complex problems.
3. Plan the solution: - out lining logical steps required to obtain the solution. In many cases these are mathematical steps.
4. Execute the plan: - determining the solution executing the logical steps in the plan.
5. Evaluate the solution. Checking the correctness of the solution retiring to different angles [6].

This general strategy will be translated to every discipline accordingly. Since the concern of this paper is physics, we will look at the application of the general strategy in physics.

Summary of the strategy is shown by Figure: 1 and Table1.



Based on the nature of the problem, the strategies can be generalized as in the following table.

**Table 1 : Alternative generalization of the steps**

Step	List of the strategies	Step	Generalized Strategy
1	Focus on the problem	I	Identity the fundamental principle
2	Describe the physics		
3	Plan the Solution	II	Outline the Solution
4	Execute the plane		
5	Evaluate	III	Check the answer

Explanation of each step can be summarized, as collected from different articles, as follows.

### **Step 1. Focus the problem**

This requires rereading and translating the statement(s) of the problem in clear words. Then visualizing the events described in the problem using real or virtual sketch [7] writing given and required quantities is part of this step

### **Step 2. Describe the physics**

- Describing the physics ideas that can support to make the problem clear [7]. Restating what is to be found by naming simple mathematical equation and translating literal picture in to a diagram that gives only essential information. In addition to these, this step includes writing down or reasoning how equations and quantities are related to principles of physics and mathematics. Converting quantities in language of physics is also task in this step.

### **Step 3. Plan the solution**

This is a step for preparation to solve the problem there by arrangement of concepts and equation. This can be: - Derivation of formula, and:

- Identification of the target variable
- If necessary finding one quantity to get another quantity needed for the target from the given information. Having as much number of equations as number of the unknowns. [7]
- Rough approximation of the solution is also task of this time.

### **Step 4. Execute the plan**

This is the most useful step which generalizes the effort made in the previous steps. It is doing all the mathematical and logical operations as planned in step 3. The tasks in this step can be named in the following three words.

- Substituting
- Solving [7]
- Reporting

## Step 5. Evaluate the solution

In this step the correctness of the solution will be checked. The evaluation may be – comparison of the solution with approximation in step 3, proportionality of the quantities, vector or scalar nature and the correctness of the unit of the calculated quantity (target quantity).

### 2.2.1. Comments and recommendation on steps of the strategy

Different individuals have given comments and rules of application on the usage of the steps in the strategies. Some of those are presented in table 2, below

**Table 2: Summary of suggested steps in strategy**

Author (s)	Activities				
	1	2	3	4	5
ReifLarkih and Bracket	-	Description	Planning	Implementation	Checking
Heller keith and Anderson	Focus the problem	Describe the Physics	Plan the solution	Execute the plan	Evaluate the solution
Adamovic and Hedden	Read the Problem	Write down given and required quantities	-	Find the correct equation	Compare the units

It is from combination of this and other articles that the above five steps of the general strategy are organized [7]

### 2.2.2. Experience of other countries

In order to accept the feasibility of the strategy it is necessary to share experience of different countries. In this regard I have selected articles presenting the results obtained in Ghana and Turkey due to application of problem solving strategies in solving physical mathematical problems.

### **2.2.2.1. Analysis of study Results of Somanya secondary technical school Yilokrobo (Ghana) (2011).**

In this school there were only 16 Natural science stream students and all are selected as strategy group students and no controlled group. The students were taught on topics of kinematics and the source was “Physics for Scientists and Engineers” by Surway and Bichner. The problem solving strategy lesson was given for 4 weeks two hours every week. They were tested before and after the intervention using three similar questions. Their responses were put in to frequency counts and converted in to percentage. Every step in the problem solving strategy was assigned points zero up to two as shown below.

Step 1 – Draw free body diagram	1pt
Step 2. List all known and unknown quantities	2 Pts
Step 3. Select useful formula (equation)	2 Pts
Step 4. Plug in, the givens and solve	2 Pts
Step 5. .... Checking	
5.1. Numerically reasonable	2 Pts
5.2. Dimensionally consistent	2 Pts [8]

According to the results of the test in all the three questions of the test in step one, drawing free body diagram, from the 16 students 12&13 students (78%), scored zero, and only 3&4 (22%) scored one, the maximum point of this step, before the intervention.

While after the intervention only one student scored zero, and the remaining 15 students got the maximum score showing 75% improvement. Similarly in the second step, 11&14 (77%) students scored the minimum point before intervention, and 2&5, the maximum point. But after the intervention only one student registered under zero leaving the remaining 15 under one again 75% improvement. Once referring to step3. Selection of appropriate formula, in pretest the maximum- minimum points ratio is 34%: 66% and in posttest it is 90%: 10%. This way if every step is observed there is an overall improvement seen on the students which on average amounts 80% after intervention.

#### **2.2.2.2. Case of DokutEyul University in IzMir (Turkey)**

In this research there were 74 students and classified in to two, 37 strategy group and 37 in controlled group students. Students in the controlled group were given only traditional instruction at the same instructional period with each lesson following the same instructional sequence like students in the strategy group. The strategy group students were trained for 8 weeks, four hour every week. The training involves both strategy implementation and traditional instruction for the strategy group. At the beginning and end of the study both the strategy and control groups were asked to respond to the same questions and, significantly, the strategy group students were found to show improvement better than the controlled group students. These and other research results as well as details on printed articles show that the strategy has got approval on its effectiveness in taking physics instruction some steps forward.[9].

## **CHAPTER THREE**

### **Research Design and Methodology**

The purpose of the study is to introduce the physics problem solving strategy and to indicate its advantage over the traditional instruction that is applied in both grade twelve and grade eleven student's text books. In spite of the fact that the strategies can be applied in all Ethiopian preparatory schools, additional information is gathered from other preparatory schools in Addis Ababa, but since the main task was performed in Higher 23 preparatory School, I would like to introduce its features related to this study. Higher 23 preparatory School is one of preparatory schools in Addis Ababa. It was established at 1948 E.C. By now there are 24 sections totally from which eight sections are for social science students, and the remaining 16 for natural science students. In each stream there are equal number of grade 11 and Grade 12 students and sections. Since the purpose of the study lies on feasibility of the problem solving strategies, in order to achieve the goal, three steps must be passed. They are: 1. Practically indicating the effects of the strategy on students understanding of concepts of physics- 2. Making sure that the strategy is not used in preparatory schools, and- 3. Evaluation of text books. The third step, that is, evaluation of the text books is of dual purpose. On one side it compares problem solving procedures of the strategies and the text books, supporting the first step, on the other side, it assures whether the strategies are applied over the country or not there by strengthening the second argument.

#### **3.1 Method of intervention and data collection**

This part is a task to answer the question “can application of the strategy improve student's achievement in solving mathematical problems?” And note that this is the main body of the research which answers the research questions.

The methodology employed in this study is to classify students of Grade eleven purposively in to two, as controlled and strategy (study) groups. Forty eight (48) average performing students were selected from each of Grade eleven Natural Science section meaning, four (4) students from each

section, then after introduction of one hour on contents of problem solving strategy the students were classified in to two groups, the study and controlled groups each containing 24 students. In addition to their normal class, they took additional classes for 1h every week for 8 weeks, Yekatit and megabit, 2009, the study groups using application of problem solving strategy and the controlled group, by use of traditional method. Before starting the intervention lesson, test of five question from chapters 4, and 5 (Dynamics and Work energy power), which was totally covered in normal classes, were given and their results were registered for comparison (written as pretest).

### **3.1.1 Intervention**

During the intervention, the controlled group students were taught on the chapters 6 and 7 (rotational motion and equilibrium) traditionally. Note that this lesson was additional to the lesson given in normal classes. But for the study group the lesson was given on the same chapters using the Problem Solving Strategy application. The steps of the strategy are explained in detail being supported by illustrative examples and the general concept of the strategy were taught for the eight weeks .Finishing the eight weeks lesson, a test of five questions of the same type was given for both groups and their result is registered (table 4&5).

### **3.1.2 Data collection instruments**

It was mentioned earlier in this paper that shortcomings of physics instruction are as a result of lack of necessary problem solving strategy, and to introduce the strategy, the task must start with proof that the strategy is not in use. For this justification two independent activities were made. They are, distribution of questioners and evaluation of text book. Questioners were used to get primary information and the text books were assessed to get proof that problem solving strategies were not used in preparatory school physics curriculum.

#### **3.1.2.1 Questioners**

Structured questioners were prepared having basically similar questions and distributed for fifty students and twenty five teachers of five preparatory schools in Addis Ababa, two of which are

private schools. Their answers were collected and categorized under related items so as to describe the desired situation

### **3.1.2.2 Evaluation of text books**

To know whether the strategies were already in use or not in students' text books and related references used by preparatory schools, two questions from grade twelve, two questions from grade eleven physics and one question from Alpha series reference book were selected and discussed in detail.

## **3.2 Method of data analysis**

To make the analysis simple and clear, the steps of the strategy were classified in to three main parts. That is, step (1), understanding the problem, and step (2), Describing physics, as step (A) Problem solving precondition (PSC). Similarly Step (3), planning, and step (4), carrying out the plan, as step (B), Problem solving performance (PSP), Finally step (5), Checking the result, as step (C) Problem solving revision (PSR). And the results scored by the students were categorized as results of steps (A), (B) and (C) given names as PSCT, PSPT and PSRT respectively. In addition to this to simplify the comparison between pre and post test results, the mean (M) value, a mathematical tool that describes the average result of all students in each test is used separately before and after the intervention as well as for study and controlled groups, and standard deviation, the distance from the mean value of each result is used (table 9-12). Furthermore frequency, number and percentage of students under lower, medium and higher scores before and after intervention for both groups (table 6-8).

# **CHAPTER FOUR**

## **Data and Data Analysis**

In this chapter data collected during the study will be analyzed according to the order and methodology explained in chapter three.

### **4.1 Data analysis of the intervention**

As mentioned in the previous chapter, the student's performance was tested before and after the intervention to see their improvement. The results are recorded as in the following two tables for controlled and study group students separately. Note that the number of students was 48, twenty four for each group, there were five questions in each session, that is, in pre and post interventions. The evaluation was made in categorized tests under PSCT (A), PSPT (B) and PSRT (C). PSCT is corrected from fifteen points, PSPT, from twenty five, and PSRT from ten total points.

Table 3: Mark list of Controlled Group Students

Code of student	Session	Test	Questions No. and results					Total
			1	2	3	4	5	
1	Pre	A	1	1	2	1	2	7
		B	3	3	4	4	3	17
		C	0	1	1	1	1	4
	Post	A	2	1	2	1	2	8
		B	5	4	5	4	4	22
		C	1	1	1	1	1	5
2	Pre	A	2	1	2	1	1	7
		B	4	4	4	4	4	20
		C	1	1	1	1	1	5
	post	A	2	2	2	1	2	9
		B	5	4	5	4	5	23
		C	2	1	1	1	1	6
3	Pre	A	1	1	2	1	1	6
		B	4	3	4	3	3	17
		C	1	1	1	1	2	6
	Post	A	2	1	2	1	2	8
		B	4	4	4	4	4	20
		C	1	2	1	1	1	6
4	Pre	A	2	2	2	1	2	9
		B	3	3	4	3	3	16
		C	1	2	1	2	1	7
	Post	A	3	2	2	2	2	11
		B	4	4	3	4	4	19
		C	2	1	1	2	1	7
5	Pre	A	2	1	1	1	2	7
		B	3	4	4	4	3	18
		C	1	1	1	1	2	6
	Post	A	2	1	2	2	2	10
		B	5	2	4	4	4	21
		C	1	1	1	2	1	6
6	Pre	A	2	2	1	1	1	7
		B	4	4	4	4	3	19
		C	1	1	0	1	1	4
	Post	A	2	1	2	2	1	8
		B	5	4	4	5	4	22
		C	2	1	1	1	1	6

Code	Session	Test	Questions No. and results					Total
			1	2	3	4	5	
7	Pre	A	2	2	1	2	2	9
		B	3	3	4	4	3	17
		C	1	1	1	2	1	6
	Post	A	2	2	2	2	2	10
		B	5	4	4	4	5	22
		C	2	1	1	1	2	7
8	Pre	A	1	2	2	1	2	8
		B	4	4	4	3	3	18
		C	2	2	1	1	1	7
	post	A	2	2	2	2	2	10
		B	5	5	4	4	4	22
		C	1	2	2	1	1	7
9	Pre	A	2	1	2	1	1	7
		B	3	4	3	4	3	17
		C	1	1	1	1	1	5
	Post	A	2	2	1	2	2	9
		B	4	4	4	4	4	20
		C	1	1	1	1	1	5
10	Pre	A	1	2	1	2	2	8
		B	4	3	4	3	4	18
		C	1	1	1	1	0	4
	Post	A	2	2	1	1	2	8
		B	4	4	4	4	5	21
		C	1	1	1	1	1	5
11	Pre	A	2	2	2	1	2	9
		B	4	3	4	4	4	19
		C	1	1	1	1	1	5
	Post	A	2	2	2	2	2	10
		B	5	4	4	5	4	22
		C	1	1	1	1	1	5
12	Pre	A	1	1	1	2	2	7
		B	3	3	4	3	4	17
		C	1	0	1	1	1	4
	Post	A	2	2	2	2	2	10
		B	4	4	4	4	4	20
		C	1	0	1	1	1	4

Code	Session	Test	Questions No. and results					Total
			1	2	3	4	5	
13	Pre	A	2	1	2	2	2	9
		B	1	4	4	4	5	18
		C	1	1	1	1	2	6
	Post	A	2	2	2	2	2	10
		B	4	4	4	5	5	22
		C	2	1	2	1	1	7
14	Pre	A	2	2	1	2	1	8
		B	4	4	4	3	3	18
		C	1	1	1	1	1	5
	post	A	2	2	1	2	1	8
		B	5	5	4	4	4	22
		C	2	1	1	1	1	6
15	Pre	A	1	2	2	2	2	9
		B	4	4	3	3	4	18
		C	1	1	2	1	1	6
	Post	A	2	2	2	2	2	10
		B	4	4	4	5	4	21
		C	2	1	1	2	1	7
16	Pre	A	2	1	2	1	2	8
		B	4	3	3	4	4	18
		C	1	1	1	0	1	4
	Post	A	2	2	2	1	2	9
		B	4	4	4	5	4	21
		C	1	1	1	1	1	5
17	Pre	A	2	2	2	2	2	10
		B	4	4	4	4	3	19
		C	1	0	1	1	1	4
	Post	A	2	2	2	2	2	10
		B	5	4	5	4	4	22
		C	2	1	1	1	1	6
18	Pre	A	2	1	1	1	2	7
		B	3	3	4	3	4	17
		C	1	1	1	0	1	4
	Post	A	2	2	2	1	1	8
		B	4	4	5	4	4	21
		C	1	1	2	1	1	6

Code	Session	Test	Questions No. and results					Total
			1	2	3	4	5	
19	Pre	A	2	1	1	1	2	7
		B	3	3	4	3	3	16
		C	1	1	1	1	1	5
	Post	A	2	1	2	1	2	8
		B	4	4	4	4	3	19
		C	1	1	1	2	1	6
20	Pre	A	2	2	2	1	1	8
		B	3	3	4	4	4	18
		C	1	1	1	1	1	5
	post	A	2	2	2	2	1	9
		B	4	4	4	4	4	20
		C	1	2	1	1	2	7
21	Pre	A	2	2	2	2	1	9
		B	4	4	3	3	4	18
		C	1	1	1	1	1	5
	Post	A	2	2	2	2	1	9
		B.	4	5	4	4	4	21
		C	1	2	1	1	1	6
22	Pre	A	1	2	2	2	2	9
		B	3	4	4	4	4	19
		C	1	1	1	1	1	5
	Post	A	2	2	2	1	2	9
		B	5	4	4	4	5	22
		C	1	1	2	1	1	6
23	Pre	A	2	1	2	1	2	8
		B	3	3	4	4	3	17
		C	1	1	1	2	1	6
	Post	A	2	2	2	1	2	9
		B	4	4	4	4	4	20
		C	1	1	1	2	1	6
24	Pre	A	1	2	2	2	2	9
		B	3	3	4	4	4	18
		C	1	2	1	1	1	6
	Post	A	2	2	2	2	2	10
		B	4	4	4	5	4	21
		C	2	1	1	2	1	7

**Table 4: Mark list of study (strategy) group students**

Code of student	Session	Test	Questions No. and results					Total
			1	2	3	4	5	
1	Pre	A	2	2	1	1	2	8
		B	4	4	3	4	4	19
		C	1	1	1	1	1	5
	Post	A	3	3	2	2	3	13
		B	5	5	5	4	5	24
		C	2	2	1	2	1	8
2	Pre	A	1	2	1	2	1	7
		B	4	3	3	4	3	17
		C	1	1	1	1	1	5
	post	A	3	2	3	2	3	13
		B	4	4	5	4	5	22
		C	2	2	2	1	1	8
3	Pre	A	2	2	1	1	2	8
		B	4	3	3	3	4	17
		C	1	1	1	1	1	5
	Post	A	3	2	2	3	3	12
		B.	5	5	4	4	5	23
		C	2	2	2	1	1	8
4	Pre	A	1	1	2	1	1	6
		B	3	4	4	3	4	18
		C	1	1	1	1	1	5
	Post	A	2	2	3	3	3	13
		B	4	5	5	4	5	23
		C	2	2	1	1	2	8
5	Pre	A	2	2	1	2	2	9
		B	4	4	4	3	3	18
		C	1	1	2	2	1	7
	Post	A	3	3	2	3	3	14
		B	5	5	4	4	5	23
		C	2	2	2	2	1	9
6	Pre	A	1	2	2	2	1	8
		B	4	3	4	3	4	18
		C	2	1	1	1	2	7
	Post	A	3	2	2	3	3	13
		B	5	4	4	5	5	23
		C	2	1	1	2	2	8

Code	Session	Test	Questions No. and results					Total
			1	2	3	4	5	
7	Pre	A	1	2	2	1	2	8
		B	3	4	4	3	4	18
		C	1	1	1	1	1	5
	Post	A	3	3	3	2	2	13
		B	5	4	4	5	4	22
		C	2	2	1	1	1	7
8	Pre	A	2	2	1	2	2	9
		B	4	3	3	4	4	18
		C	1	1	1	1	1	5
	post	A	3	3	2	2	2	12
		B	5	4	4	4	5	22
		C	2	2	2	1	1	8
9	Pre	A	1	2	2	1	1	7
		B	3	4	3	3	3	16
		C	1	1	1	1	1	5
	Post	A	3	3	3	2	2	13
		B.	5	5	4	4	4	22
		C	2	1	2	1	2	8
10	Pre	A	1	2	2	1	1	7
		B	3	3	3	3	3	15
		C	1	1	2	1	1	6
	Post	A	2	3	3	2	2	12
		B	4	5	5	4	5	23
		C	2	2	1	1	1	7
11	Pre	A	2	1	1	2	2	8
		B	4	3	3	3	4	17
		C	2	1	1	1	1	6
	Post	A	2	2	3	3	2	12
		B	5	5	4	5	5	24
		C	1	2	2	1	2	8
12	Pre	A	2	2	1	2	2	9
		B	3	4	3	4	4	18
		C	1	1	2	1	1	6
	Post	A	3	2	3	2	3	13
		B	5	4	5	4	5	23
		C	2	2	1	2	2	9

Code	Session	Test	Questions No. and results					Total
			1	2	3	4	5	
13	Pre	A	2	2	2	1	1	8
		B	3	4	4	4	4	19
		C	1	1	1	1	1	5
	Post	A	3	2	2	2	3	12
		B	5	4	4	5	5	23
		C	1	2	2	1	2	8
14	Pre	A	8	2	1	2	2	9
		B	4	4	3	4	4	19
		C	1	1	2	1	1	6
	post	A	2	3	3	3	3	14
		B	5	4	5	5	5	24
		C	2	2	2	1	2	9
15	Pre	A	1	2	1	1	2	7
		B	4	4	3	3	4	18
		C	1	1	1	1	1	5
	Post	A	3	2	2	2	3	12
		B.	4	5	5	5	4	23
		C	2	1	1	1	2	7
16	Pre	A	1	1	1	2	1	6
		B	4	3	4	3	4	18
		C	1	1	1	1	0	4
	Post	A	3	2	3	2	2	12
		B	4	5	4	4	5	22
		C	2	1	1	2	1	7
17	Pre	A	1	1	2	2	1	7
		B	3	4	3	4	3	17
		C	1	1	1	1	1	5
	Post	A	2	2	3	3	3	13
		B	5	5	4	4	5	23
		C	2	1	1	1	2	7
18	Pre	A	2	1	2	2	2	9
		B	3	4	3	4	4	18
		C	2	1	1	1	1	6
	Post	A	3	2	3	3	2	13
		B	5	5	5	5	5	25
		C	2	1	2	2	1	8

Code	Session	Test	Questions No. and results					Total
			1	2	3	4	5	
19	Pre	A	1	1	2	2	2	8
		B	3	3	4	4	3	17
		C	1	2	1	1	1	6
	Post	A	3	3	3	2	3	14
		B	5	4	5	5	5	24
		C	1	2	1	2	2	8
20	Pre	A	1	2	1	1	1	6
		B	3	3	3	3	4	16
		C	1	1	1	2	1	6
	post	A	3	3	2	2	2	12
		B	5	4	4	5	4	22
		C	2	2	2	1	1	8
21	Pre	A	2	2	1	1	2	8
		B	4	3	3	4	3	17
		C	1	1	2	1	1	6
	Post	A	3	2	3	2	3	13
		B.	5	5	5	4	5	24
		C	1	2	2	1	1	7
22	Pre	A	2	1	1	1	2	7
		B	3	3	3	3	3	15
		C	1	1	1	1	2	6
	Post	A	3	3	2	2	3	13
		B	5	4	5	5	5	24
		C	1	2	1	2	2	8
23	Pre	A	2	2	2	1	2	9
		B	4	4	3	4	4	19
		C	1	1	1	1	1	5
	Post	A	3	2	2	3	3	13
		B	5	5	5	5	5	25
		C	2	1	2	2	2	9
24	Pre	A	2	1	2	2	2	9
		B	4	4	4	3	4	19
		C	1	2	1	1	1	6
	Post	A	3	3	3	2	3	14
		B	5	5	4	5	5	24
		C	1	2	2	2	1	8

Note that on the table the code for both controlled and strategy group varies from 1-24, and the sessions, pre, and post are the result of students in pre intervention and post intervention.

There are tests, PSCT (A), Problem solving pre condition test which is combination of understanding the problem and description of physics. This part holds 0-3 points for each question which corresponds to 15 maximum points. Also PSPT (B) problem solving performance test which is combination of planning and solving mathematically is main body of the test. It holds 25 maximum points, five for each question. Finally PSRT (C) is problem solving Revision is the checking part holds 2 maximum points for each question and takes total of ten points. Pre and post tests are each corrected from 50 points. That is

Test A – 15 points

Test B – 25 points

Test C – 10 points

As shown in the above two tables, even though it is too long to analyze, rough observation shows that better results scored by strategy group students in the post test. In order to give a simple and clear explanation it is better to list the results using frequency, mean and standard deviation as shown in series of the following tables.

**Table 5.** Number and average of the total students under each range of scores in PSCT (A)

Group	Number	Pre-results			Post results		
		6-9	10-12	13-15	6.9	10-12	13-15
Controlled	24	24 100%	-	-	14 58.3%	10 41.7%	-
Study	24	24 100%	-	-	-	8 33.3%	16 66.7%

Note that all the students are under the minimum range in pretest and in posttest 16 (66.7%) scored maximum points from the strategy group, while no student is in this range from the controlled group.

**Table 6;** Number and percentage of students under each score in PSPT (B) having 25 total points

Group	Number	Pre-results			Post results		
		15-18	19-21	22-25	15-18	19-21	22-25
Controlled	24	19 76.5%	5 23.5%	-	-	14 52.5%	10 47.5%
Study	24	19 76.5%	5 23.5%	-	-	-	24 100%

During the pre- test both groups have scored the same results in general terms. Since this part is more or less the usual calculation part the improvement is high for the two groups but as can be observed from the table all the study groups scored 22-25 points while this range is achieved by only 47.5% of the controlled group students.

**Table 7:** Number and percentage of students under each score in PSRT Corrected from ten (10) points

Group	Number	Pre-results			Post results		
		3-5	6-8	9-10	3-5	6-8	9-10
Controlled	24	14 58.3%	10 41.7%	-	5 20.8%	19 79.2%	-
Study	24	11 45.8%	13 54.2%	-	-	19 79.2%	5 20.8%

As usual, in this test also nearly the same results are observed for both groups in pre – test. But in posttest the improvement by study group is by far better than the controlled one. To make the analysis more clear, let’s see the mean value of the results.

**Table 8: comparison of improvement made by the students in test A using mean and standard deviation. (Total point 15)**

Group	Number	Session	Mean	SD
Controlled	24	Pre	8	1
		Post	9.16	0.89
Study	24	Pre	7.8	1
		Post	12.8	0.69

During the pre-test the mean value of the controlled group is almost 50% of the maximum score even better than the same value of the strategy group students. But after the intervention the study groups have shown an abrupt change to mean value of 12.8.

**Table 9: Comparison on Test B (total point 25)**

Group	Number	Session	Mean	SD
Controlled	24	Pre	17.8	0.94
		Post	21.08	1.04
Study	24	Pre	17.54	1.15
		Post	23.20	0.93

Just as in table of frequency (Table 7) above, though improvement is better by strategy groups than by controlled group, the difference b/n the two is not so significant in this test.

**Table 10: Comparison on test C (total Point 10)**

Group	No	Session	Mean	SD
Controlled	24	Pre	5.16	0.86
		Post	6	0.82
Strategy	24	Pre	5.54	0.49
		Post	7.9	0.64

For the PSRT, C, the improvement made by the strategy group students is by 24.5% while that of controlled group is only by 11.5%, which shows the usual difference. Finally let's visualize the mean value of results of the three tests in one table.

**Table11: General Comparison by mean only**

Group	Number	Session	Mean		
			Test A	Test B	Test C
Controlled	24	Pre	8	17.83	5.16
		Post	9.16	21.08	6
Study	24	Pre	7.79	17.54	5.54
		Post	12.83	23.21	7.92

That the students were of the same performance before the intervention, that the intervention has brought a change on both groups and that the usage of the study matters can be approved referring to the above table.

## 4.2 Data analysis on existing application of the strategy

As mentioned in Chapter three, for this part totally 75 questioners were distributed for students and teachers of five preparatory Schools. To make the analysis simple, the questions on the questioners were categorized as questions on students' present status, that is, their potential in concepts of physics, causes of weakness of students, any information about the problem solving strategies of the students and the teachers, how problems are solved in physics classes, etc. The collected answers can analyzed as follows.

**Table 12. Data on the questioner**

Questions	Questions category	Suggested answers and no. of students		
1, 2	Students present status	Weak	Medium	Strong
		50/25	--	---
3, 4	Causes of weakness of the students	Teachers/students	Family	Books
		37/14 32/11	3/2	24/1 and 6/2
5	Students/teachers information above the strategies	Yes		No
		0/4		50/21
6	The way teachers/you solve problems	Open End		
		All agree on the traditional steps, given, required, solution then formula etc.		
7	Advantage of steps in traditional problem solving to understand i) The problem ii) Idea of physics iii) Clear way to solution	Yes		No
		6		44
		6		44
		5		45
8	Teachers usage of the strategy	Yes		No
		0		25
		Do not know the detail		

The first three questions refer to the present position of students, to be answered by both the students and the teachers. For the first question about interest of students to physics, all the participants answered that the interest of students is weak. Similarly for the second question of understanding of the subject, again all the participants gave answer as “weak” and for the reason of weakness three students and two teachers, total of five made “family” eleven teachers and twenty four students, “text book”, two teachers and six students “other references” fourteen teachers and thirty seven students made Teachers Methodology as responsible for weakness of the students. Finally, 43 participants, 11 teachers and 32 students suggested that student’s effort can also the cause for the weakness. From this part of the responses what can be taken as a fact is that at present students are weak in their performance of physics and because of this they don’t have interest to learn it as a subject, the main reason for the weakness is the existing teaching methodology. This is what is agreed by both students and teachers.

The next part of the questions were about the information they have on the strategy. All the participants agree on that the reason of weakness can be modified as lack of proper problem solving strategy and except four teachers, all have never heard of any problem solving strategy. Those who are aware of existence of the strategies don’t know the details properly, and therefore cannot use them in their classes. Instead problem solving is performed through the usual step; that is, selecting out the Given and Required quantities, writing the necessary formula, substitution of the given quantities in to the formula and solving to arrive at the solution. This again is the response all the students and the teachers. Finally as to the effectiveness of the above problem solving steps, six students respond that the steps helped them to understand the problem, only six students witnessed that they are useful in understanding the physics concept of the problem, and five students answered that they show clear ways towards the solution. The answer of the remaining students in each of the above questions is that the steps are not satisfactory to give the advantages asked in the questioners. The overall analysis on this data is that

1. The present student’s interest and capacity of understanding physics is weak.
2. The existing problem solving steps are not sufficient to achieve the desired goal in physics instruction.
3. Teachers don’t have knowledge of the strategies which are working over the world.
4. It is necessary to introduce the strategies.

### 4.3 Evaluation of how physics text books solve mathematical problems

The main purpose of this analysis is to show that physics text books of grade 11 and grade 12 students are not using problem solving strategies and at the same time, to some extent to indicate their advantages over the traditional method. For this task five problems, four, from Grade 11 and Grade 12 text book, one from Alpha problem solver series, were presented as follows.

#### 1. Grade 11 text book page 105 exercise 4.5 (a)

A car of mass 1250 kg is travelling at a velocity of 15m/s due east. The driver applies the brakes to slow the car down to a velocity of 3m/s due east. What is the work done in slowing the car down?

Using the equation above:

$$W = \frac{1}{2} m (v^2 - u^2) \quad \text{Substituting in the value}$$

$$W = \frac{1}{2} \times 1250 \times (3^2 - 15^2)$$

$$W = \frac{1}{2} \times 1250 \times -215$$

$$W = -135\,000 \text{ J}$$

It can easily be seen that except usage of formula and Algebraic calculation, no physics idea is transmitted in this process. But it is possible to make better explanatory using the strategy as follows.

**Using the strategy;**

**Step 1. understand the problem.**

The force of the brake slow down the 1250kg car from 15m/s to 3m/s on the same line. The work done by the braking force is required.

**Step 2. describe the physics.**

Since it is decelerating force, negative value is expected. When force and the displacement are parallel;

$$W = \mathbf{Fs}, \text{ Where}$$

$$\mathbf{F} = \mathbf{ma},$$

And,  $s = \left(\frac{v^2 - u^2}{2a}\right)$ , from equation of accelerated motion .

Step 3. Plan the solution

$$W = m a \times \frac{v^2 - u^2}{2a}$$

$$\Rightarrow W = \frac{1}{2} m (v^2 - u^2)$$

**Step 4. Carry out the plan.**

Substituting values in the above formula;

$$W = \frac{1}{2} \times 1250\text{kg} \times (9\text{m}^2/\text{s}^2 - 225 \text{m}^2/\text{s}^2)$$

$$W = 625\text{kg} \times (-216) \text{m}^2/\text{s}^2$$

$$\Rightarrow W = -135000 \text{ J}$$

**Step 5. Check the solution.**

- Numerically reasonable.
- The unit  $\text{kg m}^2/\text{s}^2$  is Joule
- The solution is correct

## 2. Grade 11 physics text book page 185 Exercise 8.13

Using a current of 1.5 A, a 12 V, 1.5. A heater was used to heat 100kg of water for 15 minutes. The temperature rose from 21°C to 52°C. Based on these results, how much energy would be required to warm 1kg of water by 1°C ?.

Power of heater (W)	Energy supplied (J)	Temperature change (°C)
$12 \times 1.5 = 18$	$15 \times 60 \times 18 = 16\ 200$	$52 - 21 = 31$

Use  $\Rightarrow E = mc\Delta\theta$

$$\Rightarrow C = \frac{E}{m\Delta\theta}$$

$$C = \frac{16200}{0.1 \times 31}$$

$$= \frac{16200}{3.1}$$

$$= 5226 \text{ J/kg/K}$$

As shown above, had it been lesson for teachers or university students the operation would have been sufficient. But for preparatory school students (secondary school), additional explanation is needed so as to help them grasp the idea which has impact on their future carrier.

### Using the strategy

#### Step 1. Understanding the problem.

The heater labeled 1.5A, 12V heats 100g water from 21°C to 52°C in 15 min. In this ratio the heat required to change 1kg water by 1°C is required. Note that  $t = 15 \text{ min} = 900 \text{ sec}$  and mass  $m = 0.1\text{kg}$

### Step 2. Describe the physics.

Heat required to change 1 kg water by 1<sup>0</sup>C means specific heat capacity C. The temperature difference  $\Delta T = 31^{\circ}\text{C} = 31\text{K}$  the heat energy  $E = VIt$  and this equal to the heat energy need to increase temp.  $Q = mC\Delta T$

### Step 3. Plan the solution.

$$E = VIt = Q = mC\Delta T \Rightarrow \text{from step 2 above.}$$

$$\Rightarrow VIt = mC\Delta T$$

$$\Rightarrow C = \frac{VIt}{m\Delta T}$$

### Step 4. Carry out the plan

$$C = \frac{VIt}{m\Delta T}$$
$$= \frac{12 \text{ v} \times 1.5 \text{ A} \times 9000 \text{ J}}{0.1 \text{ Kg} \times 31 \text{ K}}$$

$$\Rightarrow C = 5226 \text{ J/kg K}$$

### Step 5. Check

The unit VAs is Joule there for it is correct.

Description physics idea in step 2. Guides to pass to the next step and similarly every step is the succession of the previous step, and this makes the process simple and concept clear.

## 3. Grade 12 physics text book page 93 Exercise 2.6

A narrow pipe is 20 cm long and is open at the top and closed at the bottom. Given that the speed of sound is 340 m/s, what frequency sound might it be possible to produce by blowing across the top?

The wavelength at the fundamental frequency is four times the length of the pipe and therefore;  $\lambda = 0.8$  This corresponds to frequency of  $f = v/\lambda = 340/0.8 = 425$  And therefore it might be possible to produce sounds at odd multiples of 425 Hz, 1275 Hz, 2125 Hz, etc.

This is a more closed and short step which doesn't show any hint for the next step. Any previous knowledge is not mentioned for relation. What is meant by the problem and the solution is not included in the solution. But when the strategy is applied the condition will be quite different.

**Using the strategies:**

**Step 1. Understand the problem.**

A 20cm closed end pipe form a standing when speed of sound 340 m/s. The series of harmonic frequencies is required.

**Step 2. Describe the physics**

According to standing wave of closed end pipe, the length L of the pipe is given by;

$$L = n \frac{\lambda}{4}$$

Where n= 1, 3, 5, etc., and velocity of a wave is calculated by the equation

$$\rightarrow v = f \lambda$$

**Step 3. Plan the solution**

Combining the above equations

$$f = \frac{v}{\lambda} \Rightarrow$$

$$f = \frac{v}{4L}, \quad \Rightarrow \text{it is known that for n harmonics}$$

$$\lambda = \frac{4L}{n} \text{ and for 1}^{\text{st}} \text{ harmonics it will be}$$

$$\lambda = 4L \quad \text{therefore for n - harmonic,}$$

$$f_n = \frac{nV}{4L} \quad \text{where, n = 1, 3, 5, etc}$$

#### Step 4. Carry out

$$f_1 = \frac{340\text{m/s}}{4 \times 20\text{cm}}$$
$$= \frac{340\text{m/s}}{4 \times 0.2\text{m}} = 425\text{Hz}$$

Then since  $f_1 = 3f$ ,  $f_3 = 5f$ , etc..., the series will be 425 Hz, 1275 Hz, 2125 Hz..

#### Step 5. Check the solution

The unit is correct,  $1/\text{s} = \text{Hz}$

⇒ the solution is correct.

One can see that the step is long. But there is a very good transfer of knowledge.

#### 4. Grade 12 Physics text book page 174 Exercise 4.6

- a) What is the capacitance of a capacitor which can store 18mC of charge When the potential difference across it is 6V?

$$C = \frac{Q}{V}$$
$$C = \frac{18 \times 10^{-3}}{6}$$
$$= 3 \times 10^{-3}$$
$$\Rightarrow C = 3\text{mF}$$

- b) How much charge will be stored on the capacitor if the voltage is increased to 20V?

$$Q = CV$$
$$= 3 \times 10^{-3} \times 20$$
$$= 60 \times 10^{-3}$$
$$\Rightarrow Q = 0.06\text{C.}$$

But when the strategy is applied there are more words to explain the condition at each step.

## Using the strategy

### Step 1. Understand the problem

A capacitor by 6V holds 18mc charge, its capacitance and the charge on it when charged by 20V is required where,

$$18\text{mC}=18\times 10^{-3}\text{C}.$$

### Step 2. Describe the physics

The capacitance of a capacitor is given by;

$$C = \frac{Q}{V} \quad \text{note that the capacitance, } C, \text{ of the capacitor is Constant}$$

### Step 3. Plan the solution

a.  $C = \frac{Q_1}{V_1}$  ,                      where  $\Rightarrow V_1 = 6\text{V}$  and

b.  $Q_2 = CV_2$ ,                      where  $\Rightarrow V_2 = 20\text{V}$

### Step 4. Carry out

a;  $C = \frac{Q_1}{V_1}$

$$= \frac{18 \times 10^{-3} \text{C}}{6\text{V}}$$
$$= 3 \times 10^{-3} \text{ C/V}$$

$$\Rightarrow C = 3\text{mF}$$

b.  $Q_2 = CV_2$

$$= 3\text{mF} \times 20\text{V}$$
$$= 60\text{mFV}$$
$$= 60\text{mC}$$
$$\Rightarrow Q_2 = 0.06\text{C}$$

### Step 5. Check the solution

The answer is both numerically and dimensionally correct

#### 4. Alpha problem solver series page 262 Exercise 13

**Example 13.** The blades of a windmill start from rest and rotate with an angular acceleration of  $25 \text{ rad/s}^2$ . At any point on a blade, how much time passes before the magnitude of the tangential acceleration equals the magnitude of the centripetal acceleration?

**Solution:**  $\omega_0 = 0$  and  $\alpha = 25 \text{ rad/s}^2$

We want the time at which  $a_t = a_c$ .

$$\text{Since } a_t = r\alpha,$$

$$\text{And } a_c = r\omega^2, \text{ we get}$$

$$r\alpha = r\omega^2$$

$$\alpha = \omega^2$$

Where  $\omega$  is the angular speed reached at time  $t$ . It can be determined from equation.

$$\omega = \omega_0 + \alpha t$$

$$= 0 + \alpha t$$

$$= \alpha t \quad \rightarrow \text{ Squaring both sides, we have;}$$

$$\omega^2 = \alpha^2 t^2$$

Now we substitute this for  $\omega^2$  in the above equation

$$(\alpha = \omega^2)$$

$$\alpha = \alpha^2 t^2$$

$$\Rightarrow t^2 = \frac{\alpha}{\alpha^2}$$

$$= \frac{1}{\alpha}$$

$$= \frac{1}{25 \text{ rad/s}^2}$$

$$= 0.04 \text{ s}^2 \Rightarrow \text{ or } t = 0.2 \text{ s}$$

Using the strategies

**Step 1. Understand the problem;**

The blades accelerate at angular acceleration  $\alpha = 25 \text{ rad/s}$  the time at which centripetal acceleration  $a_c$  becomes equal to the tangential accelerations required.

**Step 2. Describe the physics**

The tangential acceleration is  $a_t = r\alpha$

And the centripetal acceleration  $a_c = r\omega^2$  and the angular speed at time  $t$  is

$$\omega = \omega_0 + \alpha t$$

$$\Rightarrow \omega = \alpha t, \quad \text{since } \omega_0 = 0$$

**Step 3. Plan the solution**

The time at which  $r\alpha = r\omega^2$  is needed. In the equation;

$$\omega = \alpha t, \quad \Rightarrow \text{squaring yields}$$

$$\omega^2 = \alpha^2 t^2$$

$$\Rightarrow r\alpha = r\alpha^2 t^2$$

$$\Rightarrow \alpha = \alpha^2 t^2$$

$$\Rightarrow 1 = \alpha t^2$$

$$\Rightarrow t^2 = \frac{1}{\alpha}$$

$$\Rightarrow t = \sqrt{1/\alpha}$$

**Step 4. Carry out**

$$t = \sqrt{1/\alpha}$$

$$t = \sqrt{1/25 \text{ rad/s}}$$

$$t = \frac{1}{5} \text{ sec}$$

$$\Rightarrow t = 0.2 \text{ sec}$$

### **Step 5. Check**

Since rad is omitted the answer is correct.

In all the examples seen above, the conclusion which can be arrived at is that student's text books and other references don't accompany their problem solving with related theoretical explanation of what is being done, which is part of the strategy and very important task to enable students grasp concepts aimed to translate through the problem

## **CHAPTER FIVE**

### **Conclusion and recommendation**

#### **5.1 Conclusion**

The main objective of the study was to show that problem solving strategy is advantageous towards students' conceptual understanding of physics than the traditional method of teaching.

As mentioned in back ground and statement of the problem, traditional problem solving instruction of physics have been with many problems and these problems can be taken as the main reason of why the necessary goal is not achieved in this sector. In order to achieve instructional goal in physics it is necessary to employ responsibly selected problem solving strategy(s). The strategy presented in this study consists five steps and it is called the general (fundamental) strategy.

The results of this study have shown that the application of the strategy has significant effect in students understanding of concepts of physics and, at large, in achievement of the desired goal towards physics instruction. To perform the study, students grouped in strategy and traditional groups were pre and post tests before and after the intervention respectively and their results were analyzed using mathematical tools, frequency mean and standard deviation and assured that usage of the strategy improves student's problem solving capacity. In addition to this text books of students were analyzed in detail towards their problem solving techniques and compared with steps of the strategy. It was proved that the tradition in the text books doesn't make clarify physics ideas which are clue for understanding the concepts. Furthermore, the feedback collected from students and teachers of different preparatory schools through questionnaires' strengthen the same facts. The experiences of other countries also have shown the advantage of using the strategy than the traditional steps. When all this findings are collected together, the following conclusions can be given on all the tasks.

.The failures of traditional education and, in turn, the importance of introducing modern approach in teaching physics and other fields is explained in different articles [ 9,3,7,1,] and papers presented by PER and other organizations. The research result in Faculty of education of Dukes Ell University (Turkey) [9] and Somanya senior High secondary technical school of

Ghana [8] prove that physics education will be effective if it is thought using the problem solving strategy than the traditional method of teaching. In the experiment (Research) Conducted in this paper Addis Ababa it is clearly shown the students thought using problem solving strategy have scored significantly higher points than those taught traditionally.

The tables in unit 4, using frequency distribution and mean of the score of results indicate the same facts. Furthermore these tables show that the areas referring to physics concept understanding is the basic difference b/n teaching traditionally and using the strategy. It is as simple as adding one plus one to conclude that conceptual understanding of basic physics ideas makes the students ready to solve the next problem etc.... The reason is that the steps of the strategy (Step 1 and step 2) forces the students to explain physics ideas related to the problem). This makes aware of what they are doing. This Habit continuous until the students become familiar with the strategically approach and then in long process, Applying problem solving strategy in physics lesson enables the students to capture the necessary knowledge in physics all the papers and the studies mentioned in this paper and the tables in chapter three and four show this fact. Therefore problem solving strategy is basic tool for student's conceptual understanding of physics than the traditional method of instruction. Assessment of grade 11 and 12 physics text books also showed that they lack problem solving strategy.

## **5.2 Recommendation**

As the details of the strategy, and experiences of other countries, and, based on this, as the scored results of the study group students of higher 23 preparatory students in this work, the conclusion is that the strategy is effective to bring about the desired change in grasping physics concepts by students. Then it may be necessary to train teachers to use the strategy in their everyday lessons. At the same time text books, teacher's guides and lesson plan formats must be organized so as to include the step of the strategies. Tests and Examination need to have ways to check performances of the students in all steps of the strategy.

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## Appendix

### 1. Lesson Plan of controlled class

School – intervention Programmer

Teacher’s Name Abau Negash

Subject – Physics

Units-- Rotational motion and Equilibrium

Duration--- 09/6/09----- 28/7/09

Objective – To enable the students to have sufficient problem solving skills.

Date	Topic	Methodology	Source
09/06/09	Rotation - Quantities - Difference b/n rotation and translation - Rotational acceleration	Using lecture method with short notes	Alpha problem solver series for grade 11 and 12
16/06/09	Torque, moment of inertia angular displacement angular momentum	Lecturing on all Dynamic quantities	
23+30/06/09	Sample examples of problem solving	Using traditional methods	
07+14/07/09	Equilibrium 1 <sup>st</sup> condition 2 <sup>nd</sup> condition---- complete equilibrium	Lecturing in conditions kinds of equilibrium	
,	Solving some examples	Using traditional steps problem solving	“

## 2. Lesson Plan for study group class

School – intervention Programmer

Teacher’s Name Abau Negash

Subject – Physics

Units----- Rotational motion and Equilibrium

Duration—07/06/09----- 26/07/09

Objective – To enable the students to have sufficient problem solving skills.

Date	Topic	Methodology	Source
07/06/09	Rotation - Quantities - Difference b/n rotation and translation - Rotational acceleration	Using lecture method with short notes	Alpha problem solver series for grade 11 and 12
14/06/09	Torque, moment of inertia angular displacement angular momentum	Lecturing on all Dynamic quantities	
21+28/06/09	Sample examples of problem solving	using all steps of the strategy	
5+12/07/09	Equilibrium 1 <sup>st</sup> condition 2 <sup>nd</sup> condition---- complete equilibrium	Lecturing in conditions kinds of equilibrium	
,19+26/07/09	Solving some examples	Using all steps of the strategy	“

### 3. Sample of examples on the intervention classes

1. The blades of a windmill start from rest and rotate with an angular acceleration of  $25 \text{ rad/s}^2$ . At any point on the blade how much time passes before the magnitude of the tangential acceleration equals the magnitude of centripetal acceleration.
2. A wheel in the form of a disk ( $I = \frac{1}{2} Mr^2$ ) is given an initial angular speed of  $1.5 \text{ rad/sec}$ . It comes to rest after rotating through  $\frac{3}{4}$  of a turn. Find the average torque exerted on the wheel if its mass and radius are  $6.4\text{kg}$  and  $0.5\text{m}$  respectively.
3. A mass of  $10\text{kg}$  is suspended from a roof by two strings which make angle of  $37^\circ$  and  $53^\circ$  from the horizontal. Find tension in each string.
4. Uniform meter stick of mass  $0.5\text{kg}$  is pivoted at a distance  $40\text{cm}$  from one end. If a  $2\text{kg}$  mass is suspended from this end, what mass must be suspended from the meter stick to be in equilibrium?
5. A uniform ladder of length  $L$  and Weight  $50 \text{ N}$  rests against a smooth wall. If the coefficient of static friction b/n the ladder and the ground is  $0.5$ , find the minimum angle b/n them for the ladder not to slip.

### 4. Pre intervention test

**Solve the following problems by showing all fundamental steps clearly**

1. A  $2\text{kg}$  block is accelerated uniformly from  $6\text{m/s}$  to  $30 \text{ m/s}$  in  $4 \text{ sec}$ . What is work done on the block during this time?
2. A man pushes a trolley loaded with goods using force  $140\text{N}$  through distance of  $25\text{m}$ . The mass of the loaded trolley is  $75\text{kg}$ . If coefficient of kinetic friction is  $0.08$ , what is what is the net work done on the trolley.
3. A  $4\text{kg}$  ball is released from height of  $80\text{m}$ . What will be its kinetic energy when it falls  $20\text{m}$  down?
4. A certain body is moved from  $X = 4\text{cm}$  to  $X = 16\text{cm}$  marks along  $X - \text{axis}$  by a force 
$$\mathbf{F} = 6\mathbf{i} + 4\mathbf{j}$$
 What is the work done on the body?
5. A  $50 \text{ Nm}$  torque acts on a wheel of moment of inertia  $200\text{kg m}^2$ . If the wheel starts from rest, how long will it take the wheel to reach an angular speed of  $7\text{rad/s}$ ?

### 5.post -intervention test

1. A Wheel starts from rest and rotates with constant angular acceleration to reach an angular speed of 12 rad/s in 3 sec. Find its angular acceleration.
2. A torque of 10Nm acts for a short time of 0.01 sec on a rotating disk. What is the angular impulse imparted on the disk?
3. A traffic light of mass 25kg is suspended from a cable so that the strings make  $30^\circ$  from the horizontal. Find tension in the strings.
4. A 1.5kg board serves as see saw for two children. One child has a mass of 30kg and sits 2m from the pivot. At what distance from the pivot must a 40kg child sit to balance the see saw?
5. A uniform 6m ladder weighing 60N leans against a friction less wall. The foot of the ladder makes angle of  $53^\circ$  with the floor. Find the minimum coefficient of static friction necessary b/n the ladder and the floor if the ladder is net to slip.

#### Result

Test	1	2	3	4	5	Total
PSCT						
DSPT						
PSDT						

#### Comments

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## 6. Questioner for students

Dear students, thank you for that you are volunteer to respond to my questioner. The purpose of the questioner is to introduce a new and better approach to physics instruction. It is prepared for purpose on physics problem solving strategy.

Please make X mark for closed end questions, and you don't have to write your name

1. General information: sex \_\_\_\_\_ Age \_\_\_\_\_ Grade \_\_\_\_\_

2. About students:

1. How is interest of students in learning physics as a subject?

High \_\_\_\_\_ Medium \_\_\_\_\_ Weak \_\_\_\_\_

2. How do you evaluate students understanding in learning physics?

High \_\_\_\_\_ Medium \_\_\_\_\_ Weak \_\_\_\_\_

3. If your answer for question No.2 is "weak", what do you think is the reason for the weakness? It is problem of:

Family \_\_\_\_\_ Text book \_\_\_\_\_ References \_\_\_\_\_

Teacher's Methodology \_\_\_\_\_ Others \_\_\_\_\_

4. It can also be due to lack of appropriate problem solving strategy.

Agree \_\_\_\_\_ Disagree \_\_\_\_\_

5. Have you ever heard of any "problem solving strategy"?

Yes \_\_\_\_\_ No \_\_\_\_\_

③. About the teachers:

1. How do your physics teacher solve physics mathematical problems?

Please write the steps in short.

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2. Do this steps make you understand: (please write "Yes" or "No").

- a) The problem clearly before starting to solve\_\_\_\_\_
- b) The idea of physics towards the problem\_\_\_\_\_
- c) Clear ways to come to the solution\_\_\_\_\_

THANK YOU

## 7. Questioner for teachers

Dear teacher thank you for that you are volunteer to respond to my questioner. The purpose of the questioner is to introduce a new and better approach in physics instruction. It is prepared for study purpose on physics problem solving strategy.

Please make X mark for closed end questions and you don't have to write your name.

### ① . General information:

Sex\_\_\_\_\_ Age\_\_\_\_\_ years of service\_\_\_\_\_

Grade you are teaching\_\_\_\_\_

### ② . About the students

1. How do you see interest of your students to physics?

High\_\_\_\_\_ Low\_\_\_\_\_ Not at all\_\_\_\_\_

2. How do you evaluate student's performance in problem solving?

Strong\_\_\_\_\_ Well\_\_\_\_\_ Weak\_\_\_\_\_

3. If your answer for No.2 is "weak", what do you think is the reason for the weakness? It is the problem of:

Family\_\_\_\_\_ Textbook \_\_\_\_\_

References\_\_\_\_\_ Teaching methodology \_\_\_\_\_

Others\_\_\_\_\_

4. It can also be due to lack appropriate problem solving strategy.

Agree\_\_\_\_\_ Disagree\_\_\_\_\_

③ . About the teachers

1 .How do you solve physics mathematical problems in your

Class?(please write the steps in short)

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2. Have you ever heard of problem solving strategies?\_\_\_\_\_

3 .If your answer is “Yes”, please write its detail in short

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4. If your answer for No.2 is “Yes Do you use them in your classes?

5. If No”, Why? \_\_\_\_\_

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THANK YOU