

**ORIGINAL ARTICLE**

**An Evaluation of Grades 9 and 10 Mathematics Textbooks  
Vis-À-Vis Fostering Problem Solving Skills**

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*Abstract*

*This study sought to evaluate the adequacy of integration of problematic situations and general problem-solving strategies (heuristics) in grades 9 and 10 mathematics textbooks. Grade 9 and grade 10 mathematics textbooks were used for analysis. Document analysis and interview were used as data gathering instruments. Document analysis was carried out on the two textbooks using Mathematics Material Analysis Instrument (MMAI) developed by Karen (1997). Interview was held with two experts from Institute of Curriculum Development and Research about the backgrounds of textbook writers. The content analysis result revealed that grades 9 and 10 mathematics textbooks have coded value of 2. This value of (2) implies low level of inclusion of problematic situations and general strategies of problem solving (heuristics). One Sample t-test analysis has also ascertained that the coded values (observed) are significantly less than the expected value. The interview made with experts from ICDR portrayed that textbooks are prepared by subject specialists who were recruited through the bid system. Besides, the interview result indicated that training was not given to the text writers before or during preparation of textbooks. This implies that grades 9 and 10 mathematics textbooks foster more memorization of facts than developing students' problem solving skills. Based on these results recommendations are forwarded.*

**Key words:** Problem-solving, Mathematics textbook analysis, Heuristics

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**INTRODUCTION**

**Background of the Study**

In Ethiopia, the development of problem-solver citizen was given considerable emphasis with the declaration of the new MOE (1994). The policy proclaims “to develop the physical and mental potential and the problem-solving capacity of individuals...(5)”.

The effective implementation of this objective requires clear understanding of the term problem-solving and the way it is realized through the curriculum content selection, organization and the selection and application of teaching-learning methodologies.

In Ethiopia, the curriculum for secondary schools (grades 9-12) is prepared nationally and is similar throughout the country.

Problem and problem-solving have been defined by different scholars. Dockers, cited in Metassebia (M.A. These Addis Ababa university 2002), stated that a problem arises when a living creature has goal but does not know how to reach this goal. Whenever one cannot go from a given situation to goal situation simply by action, there has to be recurrence of thinking. Such thinking has the task of devising some action, which may mediate between existing and desired situation. In other words, a problem occurs whenever a problem solver has a goal but lacks an obvious way of achieving that goal.

As Schofield (1998) asserted, for a given situation to be a problem it should be considered in relative sense, depending up on the individuals who confront the situation, i.e. a problem to one may be an exercise for the other. Therefore, the given situation is a problem to an individual if a situation is unfamiliar to the individual and if he/she does not have readily available means to reach a goal.

And hence, a problem can be explained as a situation that can be solved by previously learned rules, procedures and skills.

Similarly, Kurik and Rudnick (1987) explained problem-solving as an approach that an individual uses previously acquired knowledge, skill and understanding to satisfy the demands of unfamiliar situation.

To develop such skills of problem solving, the provision of well-organized curricula materials and its appropriate implementation is indispensable. In the Education and Training Policy of Ethiopian MOE (1994), it is stated that the curriculum should aim at developing problem solving capacity of society and individuals for the country’s socio-economic development. To this end, the curricula materials should incorporate challenges, which lead students towards having better knowledge, values and skills required to develop a problem solver citizen (MOE, 1994).

Textbooks for such purpose should put students as actors who engage in identifying and applying what they knew and experience as rules, principles and procedures for solving problems and constructing knowledge through the process of application, analysis, synthesis and evaluation (Boster, cited in Dawit, 2006). In order to develop the problem-solving capacity of students, textbooks should also give students an opportunity to discover knowledge by themselves rather than pouring on ready-made factual information. McNeil (1996), stated that developing problem solving abilities requires in-depth study and sustained concentration on a limited number of topics or questions on a certain limited time.

Similarly, McNeil (1996:324) stressed that meta-cognitive and cognitive strategies are the main tools for developing problem solving skill. In view of this, Stones (1994) explained that a curriculum for problems solving has to allow students to learn the heuristics of diagramming, breaking a problem in to sub-elements and working backwards. To transfer problem-solving

skill practiced and acquired in the classroom situation in to real life situation, the design of curricula materials and the provision of instruction in line with fostering problem solving skills is indispensable (Ibid.).

Mathematics is among other subjects that need incorporation of problematic situations and methodology which play a role in fostering problem-solving skill. In view of this, the National Council of Teachers of Mathematics (NCTM 1988) explained that mathematics curriculum should include opportunity for students to solve problems, learn to communicate using mathematics ideas and symbols and acquire mathematics reasons so as to develop problem- solving skill.

#### **Statement of the Problem**

The New Education and Training Policy of Ethiopia give emphasis to individuals' and society's problem-solving capacity development. To realize this objective, the development of the curriculum has been considered as one strategy. In view of this, the New Education and Training Policy of Ethiopia in MOE (1994: 5) states "the preparation of the curriculum will be in line with the stated objectives of education, ensuring that the relevant standards and the expected profiles of students are achieved."

To build problem-solving citizen, curriculum materials (teacher's guides, syllabi and textbooks) have to be prepared in line with the standards to enhance problem- solving skills. Pimm and Love (1992) confirmed that problems are at the heart of mathematics and that solving problems and learning how to solve problems is an essential component of learning mathematics. In line with this, NCTM (1988) explained that problem-solving should be the central focus of the mathematics curriculum.

Contrary to the intent of the Education and Training Policy, students' ability to solve

problems in science particularly in mathematics is gauged to be low (Haftu, 2008). Different scholars have pointed out different factors that constrain problem-solving skills of students. Of these, Metassebia (M.A. Thesis, Addis Ababa University, 2002) have evaluated the adequacy of mathematics textbook exercises in developing problem-solving skills. They reported that the majority of the exercises are factual type that develops memorization of rules.

There are three general themes that make problem-solving more comprehensive in mathematics. These are "problem-solving as context, problem-solving as skill and problem-solving as an art" (Higgeins, 1983 14). An educator who is engaged in problem-solving should give contextual (real-world) example to enhance problem-solving skills.

Problem-solving is considered as an art, when it aims at developing students' skills in independent thinking. Problem-solving is a skill, when it deals with general procedures (or rule of thumb) for solving problems such as drawing pictures, working backwards and making a list.

Mayer and Polya (1995) have developed four steps that help students solve problems successfully. These are problem translation or understanding, devising a plan, solution execution and looking back. Research conducted by Hwa, Tee, Young and Love Megking (n.d) indicates that successful problem-solving depends on the problem-solving skill, basic mathematics skill and students' characteristics.

Hembree cited in Metassebia (M.A. Thesis Addis Ababa University, 2002) indicated the correlation between students' performance and application of Polya's (1995) four-step heuristic procedures. He found that students' problem-solving skill is enhanced after application of Polya's (1995) heuristics of problem-solving. To

this end, the curriculum materials should be organized taking problem-solving at the centre. Thus, the major objective of this study is to explore the extent to which grade 9 and 10 mathematics textbooks are organized to promote students' problem-solving skills. Based on the above theoretical and research evidence, the current study tried to answer the following research questions.

1. Do mathematics textbooks contain problems that require inquiry and discovery methods of problems solving rather than facts, rules and concepts that need simple memorization?
2. Do mathematics textbooks give an opportunity for students to use heuristic strategy of problem-solving?

#### **Purpose of the Study**

Hussen and Postelthwaite, cited in Metassebia (M.A. Thesis, Addis Ababa University, 2002), believed that the curriculum of mathematics should be organized around the process of problem-solving abilities. A research carried out by Kurik and Rudrick (1987) and Schofield (1998) revealed that teaching by heuristics of problem solving approach is found to be helpful in promoting the development of problem-solving abilities and building positive attitudes and beliefs towards problem-solving. Thus, this study primarily aimed at examining the extent to which grade 9 and 10 mathematics textbooks have adequately integrated problem-solving contexts. Specifically, the following set of objectives were formulated:

1. Identifying whether the curriculum organization of grades 9 & 10 mathematics textbooks are in line with fostering problem-solving skills.

2. Assessing whether the textbooks are organized to encourage students to apply heuristics strategy.

#### **Significance of the Study**

As was explained earlier, the main goal of the Policy (Education and Training Policy) is to build the problem-solving capacity of individuals and the society. Therefore, problem-solving should be the centre of mathematics curriculum (NCTM, 1988).

As to NCTM (1988), learning to solve problems is a principal reason for studying mathematics. In spite of the centrality of problem-solving in mathematics, its role in school mathematics curriculum was not clearly established. Some mathematics educators view that it is the task of teachers to provide students with activities.

The results of the current research are significant for curriculum developers to know the status of grades 9 and 10 mathematics text and organize and revise them in tune with problem-solving processes. The results also help policy makers develop professional materials in light of fostering problem solving skills. They are also important for teachers to have awareness about the nature of the text and shape their classroom practice directed towards developing students' problem-solving capacity.

The curriculum owners (parents, teachers, students and school community), policy implementers, supervisors, teachers, school administrators, curriculum designers, regional curriculum developers, should be aware of the above facts.

#### **Delimitation of the Study**

The development of problem-solving capacity of learners is the result of the multitude of factors in the curriculum. However, this study is delimited to

examining the extent to which grades 9 & 10 mathematics textbooks promote problem-solving approach through the provision of context-related issues and adequate integration of contents that encourage students to apply heuristic method of problem-solving. Besides, the study focuses on only the textbooks rather than on teachers' guide and the syllabus.

### **Review of Related Literature.**

#### **Curriculum for Problem Solving Skill Development**

Gagn, as cited in Cotton (1995: 67), defined problem-solving as "an application of old rules to new situations and the process of ordering thinking skills to come up with unique solution". He further stated that the process of acquiring thinking skills in the classroom is the foundation for the development of critical thinker and problem solver citizens and society.

The transferability of the problem-solving skill practiced and acquired in the classroom situation in to real life situation rests on the designing of curricula materials and the provision of instructions in line with problem-solving skill (Ellote, McNeil, Savage and Armstrong, cited in Dawit, 2006; and NCTM, 1988). In line with this view, NCTM stated that problem-solving should be the focus of the school mathematics. It is because mathematics is best learned through active involvement of solving real problems. The goal of school mathematics should be to solve problems which individuals encounter in their daily life.

According to the NCTM (2004: 143), the goal of mathematics should be to:

- build new mathematics knowledge through problem-solving,
- apply and adopt a variety of appropriate strategies to solve problems, and
- Monitor and reflect on the process of mathematics problem-solving.

To achieve the above goals, problem based mathematics curriculum has to be designed because textbooks play important roles in what is taught in mathematics classroom (Cotton, 1995).

According to Rusell (1993), there are two needs for developing problem-based curriculum in mathematics. These are to find appropriate and engaging problems and the other is to develop a pedagogy whose emphasis is on the development of mathematics thinking and reasoning. It should be more than collection of activities; it must be coherent that promotes problem-solving skills.

An effective mathematics curriculum focuses on contents that will prepare students for continued study and solving problems in a variety of school, home and work settings. A well-articulated curriculum challenges students to learn increasingly more sophisticated mathematical ideas as they continue their studies (ibid). Mathematics lessons should be grounded in every day situation so that abstract concepts can be built on real experience. Organizing mathematics contents in real context helps students conceive words, pictures, data, graph and symbols by relating with real life situations.

NCTM (2004) stated that problem solving in mathematics curriculum is not a distinct topic but the organization of an entire program that provides a context for learning concepts, procedures through thinking and doing.

Furthermore, problem solving skill in mathematics is developed when a discipline is integrated with other fields, particularly with science and language. It is because integrating the subject with other fields helps learners to grasp the concept from diverse perspective. Teaching that integrated mathematics and science let

students develop and to apply important mathematical skills and concepts in meaningful situations. Students' understanding of fundamental scientific concepts is also enhanced through using integrated approach. Integrating mathematics with other disciplines can also help students see different relationships between variables (draw Pictures or graphs to indicate experimental procedures and identifying key variables) and analyze and interpret data on graph.

In 1994, the U.S congress mandated a study of curriculum that resulted in improved students' achievement. The curriculum was evaluated on the criteria "exemplary" and "promising" programs (NCTM, 2004). The criteria for being on exemplary or "promising" was (a) gain of students problem solving achievement (b) the inclusion of students from diverse economic and cultural backgrounds, and whether mathematics curriculum is developed in the context of modelling real world problem. The study revealed that there is a parallel increase between students' problem solving skills and corresponding curricula organization being "exemplary" and "promising". A research result also pointed out that there is a significant difference in maths achievement between students of problem based curricula and conventional curricula after attending 10 months.

### **The Role of Domain Specific Knowledge in Fostering Problem-solving**

To become good problem solver in mathematics, one must develop a base of mathematics knowledge as well as general rules or heuristics that guide him to solve problems.

Stones (1994) and Herbert, cited in Mcintosh (2000), explained briefly that knowing the subject matter means getting inside into it and understanding how things are related to each other and work

together. They further attest the importance of the subject knowledge for teaching problem-solving by considering the fact that people do not solve problems in areas of knowledge they know nothing about.

It is clear that most students/ teachers encounter difficulties in problem solving caused by deficiencies in understanding the subjects matter. According to Eylon and Linon, cited in Mcintosh (2000), the deficiencies might be conceptual misunderstanding or incomplete information. This is because, teachers and textbook writers assume that the students can autonomously collect relevant pieces and bits of information and create a coherent representation of the relationships.

Thompson (1998) found that those students with good mathematics knowledge base were able to use the heuristics in geometry instruction. Schofield (1998) also found that the novice usually attend to surface features of problems, whereas the expertise categorize problems on the basis of fundamental principles involved in the subject area.

Similarly, Silver, cited in Thompson (1998) found that successful problem solvers were most likely to categorize mathematic problems on the basis of their underlying similarities in structure. Martinze (n.d) also found that general heuristics had utility only when accepted by domain specific (task specific heuristics).

In general, to develop the use of general heuristics and to develop the skill of problems solving, the textbook should be organized in such a way that it contains adequate domain specific knowledge and contents that reflect the real life problems and rules and procedures for solving problems. As a result, the current study has focused on examining the adequacy of inclusion of problematic situations and heuristics strategies in grades 9 and 10 mathematics textbooks.

### **Design of the Study**

This study sought to examine the adequacy of problematic situations in grades 9 and 10 mathematics textbooks and the employment of heuristics approach of problem-solving skill. For this purpose, document analysis was carried out on specified subject textbooks.

### **Subjects of the Study and Sampling Techniques**

The target population of the study was grades 9 and 10 mathematics textbooks. Textbook organization plays a role in fostering students' problem-solving skill. Thus, analyzing the contents of textbooks in relation to their objectives (employment of heuristic approach of problem-solving and provision of problematic situations to foster problem-solving skill) is needed. To this end, the researchers included all chapters of grade 9 mathematics and grade 10 mathematics textbooks.

### **Data Gathering Instruments**

**Document Analysis:** An evaluative instrument entitled, Mathematics Material Analysis Instrument (MMAI) was adopted from Karen (1997), for this study to quantify the adequacy of problematic situation and the employment of heuristic problem-solving approach.

The Instrument (MMAI) has two categories. The first category has 5 descriptors whereas the second has 13 items or descriptors. Each descriptor in the instrument was structured into four likert scales (1=no representation, 2= low representation, 3 = moderate representations, 4= high representations).

The ordinal values 1, 2, 3, and 4 reflect the coders' perception of the extent of the provision of adequate problematic situations and employment of heuristic of problem-solving in grades 9 and 10 mathematics textbooks.

Four teachers were made to code the textbooks using the instrument designed for this purpose (MMAI). The teachers were selected for this purpose based on their long years of service. Four of them have taught mathematics for more than seven years in secondary schools.

**Interview:** Interview was also made with two curriculum experts in the Institute of Curriculum Development and Research (ICDR) about who prepares the textbooks and how the selection of people who prepared the textbooks takes place.

### **Data Gathering Procedure**

Before the actual data was gathered, the four teachers selected for this purpose were given a half day training on the nature of problem-solving curriculum and problem-solving mathematics textbook. The training was substantiated by giving practical examples in how to detect problematic situations and employment of heuristics in the text.

In the process of testing the instrument and collecting data for the final study, the following procedures were followed. Non-parametric reliability test, Kruskal Walls H-test, was employed to test the reliability of the instrument entitled Mathematics Material Analysis Instrument (MMAI) for its reliability and found indices of reliability ( $H=4.08, =.05, df=3$ ), imply that there is no difference among coders during pre-test.

### **Data Analysis Techniques**

In order to detect the extent of provision of problematic situations and employment of heuristics of problem-solving in the textbooks, the means and standard deviations of coded values of each descriptors, categories of descriptors and the descriptor as a whole were computed.

The mean indicates the extent of provision of problematic situations and employment

of heuristics of problem-solving of targeted text materials. Standard deviation indicates the agreement or disagreement of coders on their perception on the materials regarding provision of problematic situations and employment of heuristics of problem-solving. Small standard deviation indicates that coders are in close agreement in their opinion of the material and large standard deviation suggests that coders are not in close agreement in their opinion on the material. T-test was calculated to determine whether the mean coded value is above or below the expected mean. If the expected mean exceeds the observed mean at significance level, it implies that the textbooks have not adequately included problematic situations and employed heuristics approach of problem solving.

#### Data Presentation and Interpretation.

This part deals with the results obtained through content analysis on grades 9 & 10 mathematics textbooks. The results and interpretations are presented in two

sections. The first section focuses on results and interpretations of the adequacy of problematic situations in the texts. The second section deals with the nature of content organization to foster heuristic strategies. To analyze the adequacy of problematic situations in the textbooks, The Mathematics Material Analyzing Instrument (MMAI) was adopted from Karen (1997).. The instrument was rated by four teachers and the researchers and the results are presented as follows.

#### Incorporation of Problematic Situations

As shown in Table 1, the adequacy of problematic situations in the text-books to foster problem-solving skills of students, as rated by teachers, is determined by adding the coded value of each descriptors and dividing it by the number of coders [four]. And t-value was computed to see whether or not the difference between the expected mean and the observed mean is significant.

**Table- 1:** The adequacy of problematic situations of grade 9 mathematics textbook.

Content area No of item the instrument	Coders average value				Coded value				Group mean( X)	Expected mean	Std (SD)	df	t-calculated	T- critical	
	Coder 1	Coder2	Coder3	Coder 4	Coder 1	Coder2	Coder3	Coder 4							
Text	5	2.3	2.2	2.1	2.2	11	11	10.5	11	11	12.5	0.35	3	8.54	3.18

\* $P < 0.05$

As indicated in Table-1, teachers rated value of the instrument regarding the adequacy of problematic situations of grade 9 mathematics text shows that an average value ( $\bar{x} = 2.2$ ) and standard deviations (SD= 0.07) for all chapters of the textbook, implying that the coders are in agreement with the average value and the values are near to the ordinal code value(2).

Moreover, Table-1 shows that the calculated t-value ( $t = 8.54$ ,  $df = 3$ ,  $P < 0.05$ ) is greater than the critical value (3.18) implying that there is a significant difference between the group observed mean and the expected mean; i.e. the expected mean is greater than the observed mean significantly.



		Coder 1	Coder2	Coder3	Coder 4	Calculated mean	expected	SD	df	T calculated	T-critical	Coder 1	Coder2	Coder3	Coder 4	Group mean X1	SD
Text	13	28.3	27	25.3	26.5	26.0	32.5	0.77	3	16.9	3.18	1.9	2.1	1.9	2	2	0.12

\*P<0.05

As indicated in Table 3, group average coded values (x = 2.00, 1.95, 2.01, 1.99 and 2.0) and group standard deviation (SD = 0.18, 0.1, 0.09, 0.12) for chapters, 2, 3, 6, 9 and the textbook implies that coders agreed with average coded value. And, their group average coded value is near to the ordinal code value (2).

Moreover, calculated t values (t= 16.88 df =3 P< 0.05) are greater than the t critical (3.18). This implies that there is a significant difference between the calculated mean (x =26) and the expected mean (32.5) for grade 9 mathematics textbook.

**Table-4:** The Efficacy of Grade 10 Mathematics Textbook in Fostering the Employment of Heuristics of Problems Solving

Content area	No of item the inst. instrument item instrument	Coders average value				Calculator mean	expected	SD	df	T calculated	T-critical	Coded value				Group mean X1	SD
		Coder 1	Coder2	Coder3	Coder 4							Coder 1	Coder2	Coder3	Coder 4		
Text	13	27.6	27	26	27	26.9	32.5	1.07	3	10.	3.18	2.1	2.1	2	2.1	2	0.2

\*P<0.05

The data analysis and results presented in consecutive tables (from table 1 to table 4) portray the average group coded values which are near to the ordinal coded value (2) with corresponding small standard deviation regarding adequacy of problematic situations and employment of heuristics of problem-solving. Moreover, the group means of coded values, expected coded values and t -values also indicate that there is significant deference between the group coded and the expected values in

favour of the expected values. The standard deviations indicated in each row of content area portrayed the coders' agreement on the average group coded values.

In summary, grades 9 and 10 mathematics textbooks match with the ordinal coded value of 2, which implies that grades 9 and 10 mathematics textbooks contain low level of problematic situations and employment of heuristics of problems solving.

Moreover t- values revealed that textbooks do not contain problems and heuristics of problems solving adequately. As to Polya (1995), Mathematics curriculum materials with the ordinal coded value-2 are found to have inadequate incorporation of problematic situations and do not employ heuristic of problem-solving. This implies that grades 9 & 10 Mathematics textbooks emphasise rote learning and memorization, which are less supportive to the development of problem-solving skills of students. The result of the current study is consistent with the study made by Metassebia (M.A. Thesis, Addis Ababa University, 2002) and Dawit (2006). However, the result portrays that the objective of the New Education and Training Policy of the country is not adequately being implemented through the text materials. This is because the textbook (curriculum content) which was considered as one of the strategies to realize the objectives of the policy has not been properly developed.

McNeil (1996) states that the aim of education can be realized when there is consistency among the four curriculum development components (content selection and organization, the selection and implementation of appropriate methods of teaching and evaluation procedures). Of these, the selection and organization of contents is fundamental in that it shapes the selection and implementation of teaching methods and the roles of teachers and students in the classroom.

In line with this view, Thompson (1998), asserted that if materials are organized in traditional non- integrated linear fashion, they do not foster problem-solving skills of students. Since traditional mathematics materials give place for teacher-centred approach of teaching, they give less emphasis to students' learning through inquiry and discovery. Consequently, they do not provide an opportunity for students

to develop problem-solving skills (Lester, 1994).

The interview made with the two curriculum expertise and the experience of one of the researchers indicated that textbooks are prepared by subject specialists. The subject specialists are recruited through announcement of bid. It is obvious that in the bid process people who have computed with less amount of cost of preparation would be selected. The informants have also expressed that the criteria do not mostly include the text writers' knowledge of pedagogical and psychological principles of curriculum development. Besides, one of the informants said " I have never seen any training given to the selected text writers about the objectives and strategies of the New Education and Training Policy." This might have affected the Institute of Curriculum Development and Research (ICDR) so as not to get professionals who are well-trained both in the subject area and curriculum development.

However, this research has not addressed the level of experience of teachers who have participated in textbook writing, whether they have taken education courses at their university training, or any other short-term training. Thus, future researchers can conduct research by taking into account these and other variables.

Based on the results obtained in this study, the following recommendations are forwarded.

- The Institute of Curriculum Development and Research, Ministry of Education, has to duly consider the revision of the textbooks in tune with the objectives of the ETP (1994).
- The selection criteria for those who prepare the textbooks should at least include mastery of the subject area knowledge, the conceptions of curriculum development and

adequate understanding of the objectives of the MOE (1994).

- Training should be given for textbook writers on how problem solving textbook can be prepared

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