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# Research Based Mathematics Problem Solving and Proving Skills Competences

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**Abstract**

Research findings indicate that addressing problem solving and proving activities each day in the class would affect the thinking and reasoning skills of the students. We discovered that the students became more adept at mathematics problem solving and proving mathematical statements as they practiced various types of mathematical problems and mathematical statements. We also discovered that students worked more diligently on problems of interest to them. Also, some problems are better solved individually, and some are more geared as a group activity. We also proved that they develop the expected skills competences as they practices solving various mathematics problems and proving various mathematical statements.

***Keywords:*** The three Cognitive domains; mathematics problem solving procedures; individual's responsibility.

## 1. Introduction

### *1.1. Background of the study*

Some of the constraints of students' mathematics problem solving skill deficiency identified were students' poor potential to identify and use appropriate mathematical problem solving strategies and mathematical keywords or indicators, to put connections among mathematical concepts and procedures as well as mathematical ideas with different real world situations, to transform givens in to solutions or required, family and society negative attitudes about mathematics. Moreover, teachers' method of teaching mathematics and lack of opportunity for using any type of technology (computer program and software) aggravated the problem. It was found that the problems are multifaceted and accordingly the solutions require overall effort from all concerned stakeholders [1].

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Successful problem solving and proving involves the process of coordinating previous experience, knowledge and intuition in an effort to determine an outcome of a situation for which a procedure for determining the outcome is not known [3].

### *1.2. Statement of the problem*

Most of the developed countries in the world have still a special look at their citizens' performance since it is the people who will determine the future universe. To do so, one measurement of quality is providing answer to the question that "Does the students are capable of being success in mathematics?" which is basic to other fields of study.

Mathematics is an essential part of nearly in all scientific study.

In every day we use mathematics for such simple tasks as telling time from a clock, counting change after making purchase.

Mathematics is a fundamental field of study that plays a pivotal role in the development of science, technology, business, and computer science. It profoundly influences the socio-economic development of a society and civilization. Thus, it is imperative that students be equipped with strong mathematical knowledge and skills which enable them to be productive in areas where rigorous thought and precision of results are emphasized.

### *1.3. Objective of the study*

- Identifying research based mathematics problem solving and proving skills competences.

### *1.4. Significances of the study*

- Helps to have smooth students-teacher interaction.
- Indicates research based mathematics problem solving and proving skills competences.
- Improves quality of education.
- Help students to participate actively in mathematics lessons.
- It indicates implications of the study.

### *1.5. limitations of the study*

- Shortage of finance
- Shortage of human resource

## 2. Materials and Methods of the study

### *2.1. Research design of the study*

- In this research study survey design was used.

### *2.2. Methods of data analysis*

This section dealt with how the collected data was analysed, interpreted, and discussed. As a result, the data collected was analysed qualitatively by using descriptive analysis.

### *2.3. Procedures of Data Collection and Techniques of Data Analysis*

In this research study in the process of data collection, series of steps were taken. The first step in this process was simply collecting different research findings under the topic of the investigation so far on mathematics problems solving and proving mathematical statements. The second step was reading these findings again and again for depth understanding and identifying their gaps. The third procedure was collecting data, analyzing and discussing.

## 3. Results and Discussions of the study

Major Focus areas of this research were on teachers' role, students' role, students' family role, schools' role, society role, facility, government role, the three cognitive domains, mathematics problem solving and proving procedures, and mathematics teaching methods.

### *3.1. Mathematics problem solving and proving skills competence strategy 01*

**"**One of the first and foremost duties of the teacher is not to give his students the impression that mathematical problems have little connection with each other, and no connection at all with anything else....The teacher should encourage the students to imagine cases in which they could utilize again the procedure used, or apply the result obtained" [2].**"**

The Problem-Solving Process: Students can learn to become better problem solvers. There are four steps in mathematical problem solving, [2]. These are:

1. Understanding the problem (Reread, Paraphrase, Visualize, Work in pairs, identify unknown )
2. Devising a plan to solve the problem (Explain why the plan might work)
3. Implementing the plan (Experiment with Different Solution Plans)
4. Reflecting on the problem (Check if all problem conditions were made)

### *3.2. Mathematics problem solving and proving skills competence strategy 02*

#### *3.2.1. The Complex Nature of Mathematical Problem Solving*

The ability to solve and prove mathematics problems develops slowly over a very long period of time because it requires much more than merely the direct application of some mathematical content knowledge.

Problem solving performance seems to be a function of at least five broad, independent categories of factors:

1. Knowledge acquisition and utilization 2. Control 3. Beliefs 4. Affects 5. Socio-cultural contexts

Let me say a few words about each of these categories.

**4. Knowledge Acquisition and Utilization**

It is safe to say that the overwhelming majority of research in mathematics education has been devoted to the study of how mathematical knowledge is acquired and utilized. By “knowledge” I mean both informal and intuitive knowledge as well as formal knowledge. Included in this category are a wide range of resources that can assist the individual’s mathematical performance. Especially important types of resources are the following: facts and definitions (e.g. 7 is a prime number, a square is a rectangle having 4 congruent sides), algorithms (e.g. the long division algorithm), heuristics (e.g. drawing pictures, looking for patterns, working backwards), problem schemas (e. g. packages of information about problem types), and the host of routine, but not algorithmic, procedures that an individual can bring to bear on a mathematical task (e. g. procedures for solving equations, general techniques of integration). Of particular significance to this discourse is the way individuals organize, represent, and ultimately utilize their knowledge. There is no doubt but that many problem-solving deficiencies can be attributed to the existence of “unstable conceptual systems” (Lesh, 1985). That is, when individuals are engaged in solving a problem it is likely that at least some of the relevant mathematical concepts are at intermediate stages of development. In such cases problem solvers must adapt their concepts to fit the problem situation. To the extent that they are able to make appropriate adaptations, they are successful in solving the problem.

**5. Control**

Control refers to the marshaling and subsequent allocation of available resources to deal successfully with mathematical situations. More specifically, it includes executive decisions about planning, evaluating, monitoring, and regulating. Two aspects of control process have become increasingly popular as objects of research in recent years: knowledge about and regulation of cognition. The processes used to regulate one’s behaviour are often referred to as metacognitive processes, and these have recently become the focus of much attention within the mathematics education research community. In fact, recent research suggests that an important difference between successful and unsuccessful problem solvers is that successful problem solvers are much better at controlling (i.e. monitoring and regulating) their activities. It is clear that a lack of control can have disastrous effects on problem-solving performance.

**6. Beliefs**

Schoenfeld (1985) refers to beliefs, or “belief systems” to use his term, as the individual’s mathematical world view; that is, “… the perspective with which one approaches mathematics and mathematical tasks” (p.45). Beliefs constitute the individual’s subjective knowledge about self, mathematics, the environment, and the topics dealt with in particular mathematical tasks. For example, my colleagues and I have found that many elementary school children believe that all mathematics story problems can be solved by direct application of one or more arithmetic operations, and which operation to use is determined by the "key words" in the problem (Lester & Garofalo, 1982). It seems apparent that beliefs shape attitudes and emotions and direct the decisions made during mathematical activity. In my own research I have been particularly interested in students' beliefs about the nature of problems solving as well as about their own capabilities and limitations (Lester, Garofalo & Kroll, in press).

**7. Affects**

This domain includes individual feelings, attitudes and emotions. Mathematics education research in this area often has been limited to examinations of the correlation between attitudes and performance in mathematics. Not surprisingly, attitudes that have been shown to be related to performance include: motivation, interests, confidence, perseverance, willingness to take risks, tolerance of ambiguity, and resistance to premature closure.

To distinguish between attitudes and emotions I choose to regard attitudes as traits, albeit perhaps transient ones, of the individual, whereas emotions are situation-specific states.

An individual may have developed a particular attitude toward some aspect of mathematics which affects her or his performance (e.g. a student may greatly dislike problems involving percents). At the same time, a particular mathematics task may give rise to an unanticipated emotion (e.g. frustration may set in when a student finds that he or she has made little progress toward solving a problem after working diligently on it for a considerable amount of time). The point is that an individual's performance on a mathematics task is very much influenced by a host of affective factors, at times to the point of dominating the individual's thinking and actions.

**8. Socio-Cultural Contexts**

In recent years, the point has been raised within the cognitive psychology community that human intellectual behaviour must be studied in the context in which it takes place (Neisser, 1976; Norman, 1981). That is to say, since human beings are immersed in a reality that both affects and is affected by human behaviour, it is essential to consider the ways in which socio-cultural factors influence cognition. In particular, the development, understanding, and use of mathematical ideas and techniques grow out of social and cultural situations. D'Ambrosio (1985) argues that children bring to school their own mathematics which has developed within their own socio-cultural environment. This mathematics, which he calls "ethno mathematics," provides the individual with a wealth of intuitions and informal procedures for dealing with mathematical phenomena. Furthermore, one need not look outside the school for evidence of social and cultural conditions that influence mathematical behaviour. The interactions that students have among themselves and with their teachers, as well as the values and expectations that are nurtured in school shape not only what mathematics is learned, but also how it is learned and how it is perceived (of, Cobb, 1986). The point then is that the wealth of socio-cultural conditions that make up an individual's reality plays a prominent role in determining the individual's potential for success in doing mathematics both in and out of school.

These five categories overlap (e. g. it is not possible to completely separate affects, beliefs and socio-cultural contexts) and they interact in a variety of ways too numerous to name in these few pages (e. g. beliefs influence affects, and they both influence knowledge utilization and control; socio-cultural contexts have an impact on all the other categories). It is perhaps due to the interdependence of these categories that problem solving is so difficult for students [4].

## 9. Problem based learning and Mathematics

In the problem based learning model the students' turn from passive listeners of information receivers to active, free self-learner and problem solvers. It also shifts the emphasis of educational programs from teaching to learning. It enables the students to learn new knowledge by facing the problems to be solved instead of feeling boredom. Problem based learning affect positively certain other attributes such as problem solving, information acquisition, and information sharing with others, group works, and communication etc. again problems solving is a deliberate and serious act, involves the use of some novel method, higher thinking and systematic planned steps for the acquisition set goals. The basic and foremost aim of this learning model is acquisition of such information which based on facts (Yuzhi, 2003 & Mangle, 2008) [4].

## 10. Students' understanding in Problem Based Learning Environment

Presenting the students with a problem, give them opportunity to take risks, to adopt new understandings, to apply knowledge, to work in context and to enjoy the thrill of being discoverers. Tick, (2007) stated that in the student-centred learning environment that is desirable for problem based learning; the central figure of the learning-teaching process is the student. The learning objective is not the reproduction, recall and learning of passively received learning material but the active and creative engagement of students in group work and in individual study thus transferring the skills and knowledge. The individual, autonomous self-directed learning gives the freedom to the learner to decide individually and consciously on the learning strategy and on the time scale; s/he wants to follow [4].

## 11. Teachers' Role in Problem Based Learning Environment

The most important achievement of a teacher is to help his/her students along the road to independent learning. In problem based learning, teacher acts just as facilitator, rather than a primary source of information or dispenser of knowledge. Roh, (2003) argued that within problem based learning environments, teachers' instructional abilities are more critical than in the traditional teacher-centred classrooms. Beyond presenting mathematical knowledge to the students, teachers in problem based learning environments must engage students in marshaling information and using their knowledge in applied sand real settings.

Evidence of poor performance in mathematics by elementary school students highlight the facts that the most desired technological, scientific and business application for mathematics cannot be sustained. This makes it paramount to seek for a strategy for teaching mathematics that aims at improving its understanding and performance by students practically (Okigbo & Osuafor, 2008). Problem solving as a method of teaching may be used to accomplish the instructional roles of learning basic facts, concepts, and procedure, as well as goals for problem solving. Problem solving is a major part of Mathematics has many applications and often those applications represent important problems in mathematics. We include problem solving in school mathematics because it can stimulate the interest and enthusiasm of the students (Wilson, 1993), [4].

## 12. Mathematics problem solving and proving skills competence strategy 03

### *12.1. Fundamental Principles about Teaching Problem Solving*

In my study of the research literature I was able to isolate four basic principles that stood out as common results of all of the research. These principles are as follows.

I. Students must solve many problems in order to improve their problem-solving ability.
II. Problem-solving ability develops slowly over a prolonged period of time.
III. Students must believe that their teacher thinks problem solving is important in order for them to benefit from instruction.
IV. Most students benefit greatly from systematically planned problem-solving instruction.

### *12.2. Essential Components of a Systematically Planned Problem-solving Program*

Most problem-solving programs will seem for a while in the classroom. However, for a program to be successful all year and year after year, it should be made up of three components:

a. Appropriate content b. A teaching strategy and c. Guidelines for managing the program

Let us look at each component in turn.

A. Appropriate Content

First and foremost, a good problem solving program must include appropriate content. The content must be of suitable difficulty and must include at least three types of experiences designed to improve problem-solving performance. These types of experiences are the following:

1. Regular sessions devoted to solving a variety of kinds of problems;
2. Instruction in the use of various problem-solving strategies; and
3. Practice aimed at the development of specific problem-solving thinking processes and skills.

The focus of instruction should be on the solution of “process” problems, but routine one-step verbal problems and multiple-step verbal problems should also be included. Briefly, a process problem is one whose solution cannot be obtained simply by performing computations. Such problems are included because they exemplify the processes inherent in thinking through and solving a true problem (i. e a situation for which a procedure for solving the problem is not readily at hand). These types of problems serve to develop general strategies for understanding, planning, and solving problems, as well as evaluating attempts at solutions.

One reason why students have difficulty with problem solving is that many of them have not been taught how to use specific problem-solving strategies. Traditionally, most students are taught only one strategy. Choose an operation or operations to perform, and then do the computations. Several of the strategies that should be included in instruction in grades 1-8 are the following:

- Choose an operation or operations to perform, Draw a picture, Make an organized list, Write an equation, Act out the situation, Make a table or chart, Guess and check, Work backwards, Solve a simpler problem, Use objects or models

Instruction aimed at developing students' ability to use strategies such as these needs to include two phases. During the first phase students are taught how to use a particular strategy. This phase emphasizes the meaning of a strategy and the techniques involved in implementing it. After students are introduced to a strategy they are given practice using it to solve problems. The second phase is where students are taught to decide when to use a strategy. Here students are given problems to solve but they are not told which strategy to use. They must select from among the strategies they have learned the one(s) that are appropriate for solving a given problem. Both phases must be included in instruction.

A person, who is learning to play a musical instrument, say the piano, does not learn to play simply by playing musical scores. In addition, considerable time must be devoted to activities designed to help her or him master certain skills and techniques. Such skill activities (e. g. finger exercises) are an essential part of becoming an accomplished pianist. In a similar manner, the novice problem solver must be asked to do more than simply solve problems. The third of the three types of experiences involves activities designed to develop certain problem-solving thinking processes and skills. In my own work I have identified 8 thinking processes that are involved in the solution of mathematics problems. A good problem solving program includes numerous activities that focus on these thinking processes and the skills associated with them. A list of the thinking processes is given below:

### *12.3. Mathematical Problem-solving Thinking Processes (taken from Charles, Lester & O'Daffer, 1987)*

1. Understanding/formulating the question in the problem/situation
2. Understanding the conditions and variables in the problem
3. Selecting/finding data needed to solve the problem
4. Formulating sub problems and selecting appropriate solution strategies to pursue
5. Correctly implementing the solution strategy and attaining sub goals
6. Giving an answer in terms of the data given in the problem
7. Evaluating the reasonableness of the answer
8. Making appropriate generalizations

Finally, in addition to the three types of experiences discussed above, this content should be integrated throughout the entire mathematics program. Occasional attention to problem solving or including a short unit of instruction on problem solving and proving simply is not enough.

B. A Specific Teaching Strategy

Teachers must have a specific strategy for teaching the content. A teacher who is not aware of specific ways to teach problem solving often resorts to general admonitions for students to do better when they need assistance. Comments like: “Read the problem again,” “Use your head,” and “Think harder” are commonly made by such a teacher. Teacher comments such as these may encourage students to try harder, but they are of little help to students who are truly in need of help. Indeed, very few students can become successful problem solvers without the aid of their teachers. The single most challenging task for the teacher is to decide what kind of guidance to provide and when to provide lt. The teacher must play an active part during classroom problem-solving activities by observing, questioning, and if necessary, by providing direction. During the past fifteen years I have collaborated with several colleagues in the development of a teaching strategy for problem solving. This strategy has been tested and shown to be successful in quite a large number of classrooms in a variety of schools throughout the United States (see Lester, 1983 and Charles & Lester, 1984 for discussions of the results of our research). These “teaching actions” as wall them can be used in a teacher-directed activity, beginning with a whole-class discussion of the problem, followed by individual or small-group work on the problem, and ending with another whole-class discussion of the problem. A list of the teaching actions and the purpose of each action are shown below. These teaching actions cannot be used as a “formula” that will guarantee success for all students. Rather, they provide teachers with a means to guide students systematically through the process of solving problems in order to build confidence as well as competence. As students become more capable as problem solvers the teacher’s overt role diminishes.

### *12.4. Teaching Actions for Problem Solving (taken from Charles & Lester, 1982)*

**Teaching Action 1**: Read the problem to the class or have a student read it. Discuss vocabulary and the setting of the story as needed.

**Purpose**: Illustrate the importance of reading problems carefully for good understanding.

**Teaching Action 2**: Ask questions related to understanding the problem. Focus on what the problem is asking and which data are needed to solve the problem.

**Purpose**: Focus attention on important data in the problem and clarify confusing parts of the problem.

**Teaching Action 3**: Have students suggested possible solution strategies? Do not censor or evaluate ideas at this time. (As students become more successful, this action may be eliminated.)

**Purpose**: Elicit ideas for possible ways to solve problems. Encourage flexible thinking and exploration.

**During Students’ Solution Efforts**

**Teaching Action 4**: Observe students as they solve the problem. Ask them questions about their work.

**Purpose**: Diagnose students’ strengths and weakness in problem solving. Develop reflectiveness about their work.

**Teaching Action 5**: Provide hints for students who are hopelessly stuck or who are becoming too frustrated. Repeat understanding questions needed.

**Purpose**: Help students past insurmountable obstacles in solving a problem and reduce the chances of the development of negative attitudes. Help them learn how to use particular strategies.

**Teaching Action 6**: When students get an answer, require them to check their work against data in the problem.

**Purpose**: Develop students' ability to evaluate their work.

**Teaching Action 7**: Give students who finish early a variation of the original (do this with all students as time permits).

**Purpose**: Help students learn to generalize their solutions.

**Class Discussion After**

**Teaching Action 8**: Discuss students' solutions to the problem. Identify different ways the problem might be solved.

**Purpose**: Help students learn when to use a particular strategy and how to use it efficiently. Encourage flexibility in solving problems.

**Teaching Action 9**: Compare the problem just solved with problems solved previously and discuss any variations that may have been solved.

**Purpose**: Foster transfer of learning.

**Teaching Action 10**: Discuss any special features of the problem such as misleading information.

**Purpose**: Help students recognize problem features that influence how problems are solved.

**C. Guidelines for Managing the Problem**

In addition to knowing what and how to teach, the teacher should be provided specific suggestions regarding the management of the program. In particular, the teacher must know how to deal with issues such as:

1. The amount of time to devote to problem solving

2. Ways to group students for instruction (allowing students to work on problems in groups of three or four has been shown to be quite successful).

3. Adjusting instruction for high and low achievers in the same classroom

4. How to evaluate students' performance

5. How to create and maintain a positive classroom climate for problem solving [3].

**13. Summary**

In this research paper we have attempted to provide some perspective about the nature of mathematical problem solving, proving mathematical statements and we have offered several suggestions as to how to begin to implement a mathematics program that has problem solving at its core. Yes, mathematical problem solving is difficult for children to do and it is difficult for teachers to teach. However, helping children to be better problem solvers in mathematics is not only an extremely important goal, it is also the most challenging and exciting one that a teacher can have. If we were allowed to give only one bit of advice to a teacher who was planning to begin to make problem solving and proving the focus of instruction, it would be to remember that children are natural problem solvers. The teacher's job is to try to develop this natural ability to its maximum extent and to add to the already extensive repertoire of problem-solving and proving techniques that children have at their disposal [3].

**Mathematics Problem solving and proving skills Competences should consist of the following**:

- Teacher's role
- Students' role
- Schools' role
- Students' Family's role
- Providing Technology (computer programs and software) based mathematics teaching
- Students' should identify and use appropriate mathematical problem solving strategies and mathematical keywords or indicators,
- A better approach to solve mathematical problems and mathematical statements is:

Step 1 Understanding the problem, Step 2 Devising a plan to solve the problem, Step 3 Implementing the plan, and Step 4 Reflecting on the problem.

- Developing skills and confidence through continuous practices in solving various mathematics problems and proving various mathematical statements.
- Mathematics teachers should appreciate their students for their success in mathematics.
- Problem solving performance seems to be a function of at least five broad, independent categories of factors: Knowledge acquisition and utilization, Control, Beliefs, Affects and Socio-cultural contexts.

**14. Conclusion**

According to the findings mathematics problem solving and proving skills competences are:

**Teacher's role**

The most important achievement of a teacher is to help his/her students along the road to independent learning. In problem based learning, teacher acts just as facilitator, rather than a primary source of information or dispenser of knowledge. Roh, (2003) argued that within problem based learning environments, teachers' instructional abilities are more critical than in the traditional teacher-centred classrooms. Beyond presenting mathematical knowledge to the students, teachers in problem based learning environments must engage students in marshaling information and using their knowledge in applied and real settings [4]

**Students' role**

- ❖ Students must solve many problems in order to improve their problem-solving ability.
- ❖ Problem-solving ability develops slowly over a prolonged period of time.
- ❖ Students must believe that their teacher thinks problem solving is important in order for them to benefit from instruction.
- ❖ Most students benefit greatly from systematically planned problem-solving instruction.

**Schools' role**

Fulfilling appropriate resources for mathematics teaching and learning processes like: Text books, Reference books, Markers, Black board/white board, Library, Appropriate mathematics teaching aids, clean classrooms, experienced mathematics teachers etc

**Students' Family's role**

- ❖ Following up the progress of their children learning in mathematics
- ❖ Controlling and evaluating their children's day today academic works in mathematics
- ❖ Fulfilling their children academic requirements in mathematics
- ❖ Giving encouragement and support to their children in mathematics
- ❖ Prizing their children for their success in mathematics

Providing Technology (computer programs and software) based mathematics teaching Students' should identify and use appropriate mathematical problem solving strategies and mathematical keywords or indicators,

Society negative attitude towards mathematics should be improved, A better approach to solve mathematical problems and mathematical statements is:

Step 1 Understanding the problem, Step 2 Devising a plan to solve the problem, Step 3 Implementing the plan, and Step 4 Reflecting on the problem.

Developing skills and confidence through continuous practices in solving various mathematics problems and proving various mathematical statements.

Mathematics teachers should appreciate their students for their success in mathematics.

Problem solving performance seems to be a function of at least five broad, independent categories of factors: Knowledge acquisition and utilization, Control, Beliefs, Affects and Socio-cultural contexts.

As listed above the main contents of mathematics problem solving and proving skills competences are interlinked so that they should be implemented properly. As a result:

- Students' develop an in-depth understanding of the fundamental principles and techniques of Mathematics.
- Students' develop Mathematical thinking, reasoning and an appreciation of Mathematics as a primary language of science.
- Students' develop Mathematical skills needed in modeling, proving and problem solving practical problems.

**15. Recommendation**

Mathematics problem solving and proving skills competences depend on the above elements stated in the conclusion section. To produce knowledge-full, skilled, competent, problem solver and attitudinally matured students so that the above elements need to be properly implemented. Accordingly,

- Teachers should play their roles to develop students' mathematics problem solving and proving skills competences,
- Students should play their roles to have the skills of mathematics problem solving and proving skills competences,
- Students' Families should contribute their role to improve their children's mathematical problem solving and proving skills competences,
- The school environment should be safe, should have: text books, reference books, markers, boards, etc to produce problem solver students.
- Mathematics teachers' should use appropriate mathematics teaching methods for better understanding of the students,
- Providing Technology (Computer programs and software) based mathematics teaching
- Students' should identify and use appropriate mathematics problem solving strategies and mathematical keywords or indicators,
- Societies negative attitude towards mathematics should be improved,

- Focusing on students centered mathematics teaching method/approach,
- Group discussion and then whole-class reflection based approach,
- Proper instruction in the classroom should be given to the students
- All the concerned stakeholders should contribute their own part for production of skilled, attitudinally matured, with the required mathematics problem solving and proving skills competences, and problem solver students.
- Mathematics teachers should motivate their students for their success in mathematics

- Finally in order to produce innovative and bright mind students, who is the future universe of the globe, all the concerned stakeholders should play and discharge their responsibilities.

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