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Research Article

The effectiveness of a program for developing the skills of mathematical thinking for first year preparatory pupils

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Abstract

This research aims to examine a suggested program based on student activity for developing mathematical thinking skills for first year preparatory pupils in Israel and for measuring the effectiveness of a proposed program. The researcher uses the experimental approach to examine the effect of the proposed program on seventh graders in Israel and the study relied on the mathematical thinking test and on the proposed teaching program. The sample of the study consisted of 136 male and female students. The experimental group consists of 66 male and female students, and the control group consists of 70 male and female students. The experimental treatment of the results led to the following conclusions; here are significant differences between means of pre-and post-test scores of experimental group on mathematical thinking. There are significant differences between means of post-test scores of experimental and control groups on mathematical thinking the program achieved high effectiveness in developing mathematical thinking skills. The importance of the research lies in the fact that it benefits teachers in identifying the levels of mathematical thinking for their students, which provides an opportunity to develop them, and to know the importance of mathematical thinking and its exploitation in the educational process.

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Introduction

Contemporary education aims at the comprehensive development of the learner; it is concerned with helping him to acquire information and skills. It focuses on enabling the student to acquire different methods of thinking in order to be able to solve the problems facing him in his daily life, and to acquire the skills that are needed in dealing with our ever-changing world. (Anthony & Walshaw, 2009).

Interest in mathematics education is no longer limited to obtaining information, but rather to find the means for obtaining it and to give attention to its teaching strategies and the various aspects of learning mathematics. It cannot be judged that there is a method of teaching mathematics that it is better than other methods of teaching. There may be a better method of teaching than another method of teaching in certain aspects, but not in all of them, and this only depends on the educational situation in which the teacher and the student are found. Nor is it possible to distinguish between the methods since all methods are used combined during math teaching. It is important that the teaching process be based on the learner, that the learner acquires the experience that lasts with him, and that the active positive participation of the student during the learning process is what improves his motivation and inclination to learn mathematics, as it crystallizes the learner's thinking style and develops it (Algani, 2019). Einat Heyd-Metzuyanim (2016) concluded that the conceptual method leads to the development of learning mathematics among students and increases their motivation to study mathematics. She also pointed to the strong relationship between

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difficulties in mathematics and the traditional method of learning, which leads to a fear of mathematics and math tests which she sees as a vicious cycle: Ritual Learning → Difficulties in Mathematics → Math Anxiety → Ritual Learning.

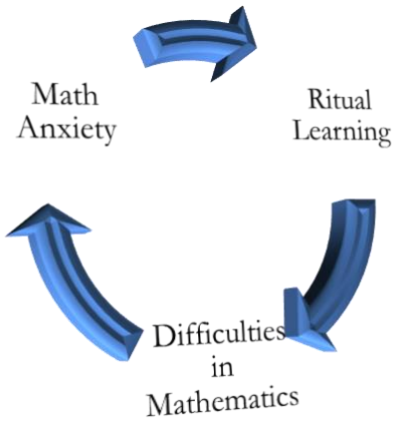

Figure 1.
Vicious Cycle

Many educators and researchers in the field of mathematics education (Mason, Burton, & Stacey, 2010; Borromeo, 2015; Singh, & Singh, 2015) emphasize the need to pay attention to mathematical thinking and its development among learners, because the development of mathematical thinking skills plays an important role in improving mathematics education and in developing motivation and achievement in this field of study.

We know that mathematics plays an essential role in the development of the individual and society and is considered an innate ability in the human mind which researches and analyzes facts to reach specific results. Mathematics is considered a basic subject taught in all stages, and its importance and great role cannot be overlooked. Algani (2018) sees that mathematics organizes logical proof, and determines the validity of a certain hypothesis. It employs several modes of thinking, organizes logical thinking to validate truths, and employs induction to generate mathematical knowledge. Teachers of mathematics develop curricula that will meet the requirements of the times and the needs of individuals as they set goals for each educational stage. It is important for teachers to understand what mathematical thinking is, so that we can develop plans, programs and events to develop mathematical thinking skills among students.

Mathematical thinking refines human thinking, and a student who can think with great mathematical skills can reach his goals faster. Scientists have been concerned with their various specializations with the issue of thinking, and many of them have tried to develop definitions that define its various concepts, as it can only be developed by understanding different concepts.

According to Alkhateb (2009), thinking is a process, consisting of mental processes and skills that include;

- Basic thinking, which is uncomplicated mental activities that require § Some of Bloom's taxonomy skills (knowledge and remember, understanding, application). § Inference skills that have their roots in logic and philosophy.
- Complex thinking, which is a set of complex mental processes that includes critical thinking, creative thinking, problem solving, decision-making, and epistemological thinking, as well as high level of thinking (analyze, evaluate and create thinking).

Algani (2018) says that thinking is a system of skills, strategies and content of knowledge in a planned way, to enable the thinker to generate the product of his new ideas. And Aubrey and Godfrey (2006), believe that mathematical thinking skills are needed for problem solving through critical and creative thinking. Battista, (2007) also showed that thinking is a skill that consists of several separate or unrelated cognitive processes which are used after grouping or joining facts together to achieve the desired result or goal. Thinking skills are considered tools for thought, and the level of efficiency in using these tools determines the level of mental effectiveness. According to Ruggiero (1994:23) thinking skills are defined as a mental activity in which an individual acquires information.

Many researchers also contributed to the definition of the thinking, such as Beyer (2001) who defines thinking as a mental process in which the learner can do something meaningful through the experience that he is going through. Wilson, (2002) believes that it is a mental process through which many things are known, remembered, understood and accepted. Mann (2006) also stated that mathematical thinking is a set of mental activities and processes that a student performs when facing a mathematical problem. Additionally, Siswono (2011) showed that mathematical reasoning is a form of mental thinking or activity related to mathematics, which depends on a set of aspects of thinking (inductive - deductive). The researcher believes that thinking skills are a mental activity that helps to quickly form an idea, discover a concept, infer generalization, solve a problem, or make an appropriate decision.

It is clear from the previous definitions that mathematical reasoning is based on a set of mental processes of inferential thinking, symbolic thinking, contemplative thinking, and mathematical proof.

Carraher and Schliemann, (2007) stated that thinking is necessary for learning. As students move from one teacher to another, their thinking ability is strengthened if the patterns of thinking are repeated in the many content areas, and that the subject matter, such as mathematics, requires an understanding of the concepts, theories and standards that contributed to the formation of that subject.

The researcher believes that when the learner thinks about mathematics, he/she is reformulating the mathematical sentence into a symbolic expression or an algebraic equation, or thinking about converting it into a geometric shape. The learner then uses those fledgling ideas when solving verbal problems by thinking about the relationships involved in the subject matter and the steps required for the solution of the problems.

This study is therefore an attempt to propose a program for the Development of Mathematical Thinking Skills for First Year Preparatory Pupils. In fact, the use of mathematics for the scientific method of thinking appropriate to the stages of the learner's growth helps to develop mathematical thinking for him through: understanding and comprehending, developing and testing hypotheses, application, observation, interpretation, and measurement. Through his exploration and understanding of the mathematical topic, the student's thinking style is changed affirmatively and builds a solid foundation that raises his level of thinking (Algani, Y., 2018).

The first task in teaching students to develop their thinking abilities is to define the thinking skills that should be developed for them in all the stages of teaching mathematics. There is general agreement that focusing on fewer skills is better than focusing on many skills. Also, there are common basic skills in most curriculum tasks such as gathering information or arriving at the meaning of something, and what this means, such as remembering, understanding, applying, and analyzing information that may be related to specific skills or may require specific qualitative skills. Clements, Fuson and Sarama (2019) proposes an introduction to analyzing knowledge content requirements and identifying the needs of the learner in order to arrive at the best list of appropriate skills to be acquired naturally while teaching.

In his articles, Algani (2018; 2019) stresses the importance of the teacher's role in developing creative and critical thinking among students through conceptual learning and reducing procedural learning. He also believes in the importance of relying on the advancing technical skills of the 21th century in developing the capabilities of the student and raising his levels of thinking. Algani also talks about the importance conceptual learning in raising the level of mathematical thinking and overcoming mathematical problems and fear of mathematics. The development of mathematical thinking skills is intended to develop educational mathematical experiences and abilities through a climate characterized by freedom and flexibility. In such a climate, the students are mentally active and their level of readiness to gain the largest possible amount of expertise in various fields is raised through positive attitudes, active practices, tools, educational methods and non-traditional teaching methods (English, 2013). According to Treffinger (1996:103), the development of thinking skills includes the following:

- Developing the capacity for sound thinking.
- Developing the ability to imagine.
- Developing the capacity for sensory perception.
- Developing the ability to solve problems

Hogland (1997:82) talks about the importance of developing a child's thinking by training him in classification, arrangement, and other mathematical skills that broaden the child's perceptions about shapes, types, quantities, colors and dimensions, while realizing the relationships between them. Albert et al (1998:141) showed that a child can also

be trained in problem-solving methods and the development of basic thinking and creative thinking by guidance in the following abilities:

- Finding facts and identifying and solving problems.
- Thinking about what is being said or read.
- Using the meanings provided by the author to stimulate his personal thoughts

Here is a list of some thinking skills that can be developed while teaching mathematics:

- Applying rules, theories and facts.
- Analyzing relationships and identifying each relationship.
- Discovering relationships.
- Knowing the statistical information and the ability to read, interpret and understand its implications.
- Using charts and tables to give specific connotations.
- Extracting generalizations, facts, principles, rules and theories.
- Distinguishing facts and assumptions.
- Problem Solving.

Algani (2019) stated-argue that developing students' thinking skills depends on several factors, including relying on the learner to conduct his own research and exploration and giving him an opportunity in the educational interaction that suits his mental abilities in order to develop them in an optimal way. It is important for decision makers in the Ministry of Education to develop programs and in the mathematics curriculum in order to develop thinking skills with all their components among students, and teachers must also promote these skills among students at all levels of learning (Algani, 2018). Mathematical thinking is thus an important axis in the content of the mathematics curricula, and this is what we find clear in the document of the International Standards for School Mathematics Teaching published by the National Council of Mathematics Teachers (NCTM). Mathematical thinking is one of the main goals of teaching and learning mathematics to all students at all levels of education and at all ages. Likewise, mathematical reasoning is not limited to just formal proof, but also includes a wide range of capabilities that students must possess and be able to possess, which is represented in NCTM, 1989. Perhaps the most prominent of these operations and skills include:

Table 1.
The Skills according to the NCTM

Mathematics Skills	Explanation
Induction	This is a logical process that helps extract general states from a partial one, and to discover potential relationships,
Generalization and abstraction	A logical process that applies to a group of things, which is the expansion to become more general and comprehensive: for example, in geometry.
Symbolism	Definition of the symbol as the sign, relationship, and representation of a mathematical process, Symbolic thinking is the abstract thinking stage that is far from the concrete stage, for example, in solving geometry and algebra.
Logical thinking	This is the transition from one stage to another, through a logical sequence, citing clear rules
Guessing	Through guessing the student describes and explores mathematical theories? with physical or logical materials.
Deduction:	Through deduction, mathematical theory is generalized.
Modeling	This is a very important tool, through which data and solutions can be represented. Through modeling, many phenomena and mathematical interpretations are explained.
Mathematical proof	We rely on mathematical axioms and the results of these axioms (theories), through which logical evidence for the validity of a mathematical theory is given.

From the table (1) above, it is clear that mathematical thinking is important in helping pupils to solve exercises and mathematical problems, perceiving relationships and understanding the dimensions of the problem or mathematical exercise. Research is required on the teaching approaches that suit slow learning pupils in order to develop mathematical thinking for them through the proposed program in the current study.

Many mathematics teachers are interested in minimum levels of thinking and show a lack of interest in the main goal, which is develop mathematical thinking, and the need for the learner to know how to think in a mathematical manner, and to properly interpret the words or symbols used in mathematical problems. They are unaware of the importance for the learner to be able to understand what he reads of mathematical relationships or models.

The importance of the research lies in the Preparing the Program for developing mathematical thinking skills which is based on the principles of active learning. Also, Identifying the difficulties of mathematical thinking skills reading mathematics, their causes and the remedial ways of it, additionally, preparing mathematical thinking test.

And the study hypotheses can be summarized as follows:

- There are positive significant differences between the means of pre-and post-test scores of experimental group regarding Mathematical thinking.
- There are significant differences between the means of post-tests scores of experimental and controlled groups regarding Mathematical thinking.
- There is effectiveness of the suggested program based on student activity on developing the skills of mathematics thinking.

This study will benefit teachers and decision makers in the Ministry of Education in identifying levels of thinking and their importance, which gives them the opportunity to develop them, organizing and displaying educational content based on student thinking level, and developing and refining mathematical thinking skills among students through appropriate educational materials and activates to prepare their desired personality.

It is clear that the method of teaching mathematics and the quality of the material has a great role in learning mathematics. So, the researcher is concerned with preparing a Program based on student activity to develop Mathematical thinking skills for the first-year prep pupils.

The research aims to Preparing a suggested program based on student activity for developing mathematical thinking skills for the first-year prep pupils, and to Measuring the effectiveness of the suggested program based on student activity for developing the mathematical thinking skills of the first-year prep pupils.

As the researcher designed a teaching program based on a problem-solving strategy in order to develop mathematical thinking.

Problem of Study

The problem of the research can be stated in the following main question: What is the effectiveness of a program based on student activity to develop mathematical thinking for first year preparatory pupils?

A corollary to this question is the following sub-questions:

- What are the features of the suggested program in mathematics with the aim of developing the mathematical thinking of the pupils?
- What is the effectiveness of a program for developing the mathematical thinking of the first year prep pupils?

Method

Research Model

The researcher based his study on experimental methodology. In this approach, the experimental data are collected concurrently during the study, are analyzed, and the results are merged during interpretation. The researcher used the experimental approach with both pre- and post- semi-experimental designs for two experimental groups (Experimental Group and Control Group), (Campbell, 1963), which aims to examine the effect of research and to measure the effectiveness of the suggested program in mathematics in Arab schools in northern Israel.

Participants

The research community consists of students of the first preparatory grade in Arab schools in north Israel, in the academic year 2020 /2019 (first semester). The sample of the study consisted of 136 male and female students. The experimental group consists of 66 male and female students, and the control group consists of 70 male and female students.

The groups were divided by relying on the mathematics teacher and their previous scores, and the researchers have taken a Pre-Test for the two groups, so that by implementing a T- Test to the two groups, they were Not Statistically Significant, as it will be clarified later.

Data Collection Tool

The study relied on the mathematical thinking test, and the researcher chose inductive thinking and inferential thinking, completing and realizing the link, and recognizing and analyzing relationships, and solving problems as factors and dimensions to measure the thinking of students through the mathematical thinking test designed by the researcher.

To calculate the coefficients of simplicity, coefficients of difficulty, and variance, the researcher found them for each of the vocabulary of the mathematical thinking test. Then the average of each one is found.

Table 2.

Illustrating the Ease and Difficulty Coefficients, as well as the Variance of the Test Vocabulary

	Coefficients ease	**Difficulty coefficients**	**Contrast**
Put these numbers down after relationships Understanding and analyzing relationships	0.933	0.067	0.062
Induction	0.872	0.0173	0,0143
Logical reasoning	0.970	0.030	0.029
Complete the links	0.967	0.033	0.032
Realize the link	0.924	0.076	0.070
Problem Solving	0.939	0.061	0.057
Mean	0.972	0.073	0.068

Proposed Teaching program

The Mathematics Thinking Skills Development Program must have clear and specific goals, and it must include appropriate content to develop mathematics thinking skills according to specific teaching strategies appropriate to the level of students and according to the age group (11-13 years) for the first preparatory grade students. It should also include activities that are consistent with their needs, capabilities and preparations. It also includes training, skills, issues and problems that measure their level of development and the development of their skills and thinking.

Component of Program for the first preparatory grade students

The foundations of preparing the program: The preparation of the program depends on the general objectives of math teaching in general, and the goals of teaching math thinking in particular.

Teaching algebra and statistics at the preparatory stage: Teaching algebra should depend on the students' understanding of the concepts and processes and studying the basic principles of algebra. This is important for the student because he cannot achieve the desired success or progress in his studies unless he understands these basic principles through which he reaches a level of skill on which he can build his following studies.

The general rule in teaching algebra should be that understanding ideas and solving problems must precede the expression of symbols and the conduct of operations, and then students can study the procedure and solve the algebraic equations.

Teaching strategy in the proposed program: The researcher relied on several teaching strategies when preparing the proposed program. Any combination of strategies can be made in proportion to developing math thinking skills, preparing program lessons and building tests, and the most important of these strategies is listed below:

Problem solving strategy: This strategy is used when presenting problem solving and includes: thinking the problem - realizing the relationships between data and requirements - analyzing relationships - developing a solution plan - thinking about a solution - implementing a solution plan - reviewing the solution.

Program content: The Mathematics Thinking Skills Development program includes (6) lessons (3 hours each lesson) as follows:

Table 3.
Lessons of the Proposed Program in Developing Mathematics Thinking

(Lesson one) Understanding and analyzing relationships	(Lesson two) induction	(Lesson three) Logical reasoning	(Lesson four) Complete the links	(Lesson five) Realize the link	(Lesson six) Problem Solving
Degree of forced reduction	Plural substitution property	Even number	Words of mathematics	Swiping property	Reverse multiplication
The numerical value of an algebraic amount	Collect equal numbers	The initial number	Algebraic limits arrangement	Algebraic amounts	The relationship between the sides of a triangle
Gregorian calendar	Foundations theory	initial number	Arrange algebraic sums	Algebraic relationships	The symbolic expression of the area of geometric figures
Rough estimate	theory of division in the foundations	Full square base	Algebraic relationships	Foundations theory	Solve an issue about the side characters of a cube
Algebraic factors	Base square sum of two quantities	Divergent	Geometry relationships	Set the solution to the equation	Deduce data from a graph

With these steps, the researcher considered the program valid for application to the experimental group of individuals in the research sample.

Results

To get to know the results of the research experiment, the researcher calculated the mean and the standard deviation of the mathematical thinking test scores in the pre and post-test. The significance of the statistical differences between the mean scores of students of the experimental and control groups before and after the experiment was calculated. In the following, the researcher tries to test (accept - reject) the following research hypotheses:

There are positive significant differences between the means of pre-and post-test scores of experimental groups regarding mathematical thinking

To identify the significance of the differences between the experimental and control groups in the pre- test of the mathematical thinking test to verify the validity of the first hypothesis, the researcher has found the mean of the degrees and standard deviations and calculating the values of "T" and the following table shows these data and the significance of the differences.

Table 4.
Mean, Standard Deviation, and "T" Values between the Experimental and Control Groups of the Mathematical Thinking Test in before Application

Mathematical thinking test	mean	Sd	t	value of the tabular t	p
Experimental group	16.85	8.14	0.726	1.98	P=0.09
Control group	18.17	12.50			P>0.05, (not statistically significant)

The results in the previous table show the convergence of the mean of the experimental and control groups in the mathematical thinking test, and the value of the T- Test between the mean scores of the pupils of the experimental and controlling groups that indicate lower values than the tabular "T" values. This indicates that there are no statistically significant differences between the members of the two groups. This also confirms the rejection (non-acceptance) of the first assignment for tests only.

There are significant differences between the means of post-test scores of experimental and controlled groups regarding mathematical thinking.

The researcher calculated the "T" values to determine the significance of the difference. The following table shows the average scores, the "T" values and the significance of the differences for the experimental group.

Table 5.

Average scores, the "T" values, the mean of the difference between the pre and post mathematical thinking trends on the experimental group

Mathematical thinking test	mean	Sd	t	value of the tabular t	p
Pre – test	18.17	12.50	35.57	2.00	P=0.01
Post- test	91.36	12.46			P ≤ 0.05 (statistically significant)

The results in the previous table indicate that there is a clear difference between the average scores of students in the pre and post-test of the mathematical thinking test, which indicates the effectiveness of the program in developing mathematical thinking skills and confirms acceptance of the second hypothesis.

To verify the validity of the third hypothesis

There is effectiveness of the suggested program on developing the skills of mathematics thinking

The level of statistical significance, however large, does not clarify the number / extent of the differences produced between the research groups and is not concerned with the effect of the independent variable on the dependent variable.

Hence the need to measure the so-called impact size or scientific significance of the results of the research. This is done by calculating the percentage of variance in the dependent variable (research results) that can be traced back to the influence of the independent variable (experimental treatment) which the researcher aims to study

The researcher used the ETA square (2η) to calculate the correlation coefficient of the effect size which provides a descriptive measure of the correlation between the samples in question and is calculated from

=Error! η^2

Table 6.

Eta Squared Values and their Statistical Significance for the Experimental Group Students in the Mathematics Reading Tests

Mathematical thinking test	Number of group members	Degrees of freedom	Calculated value of t	Value of the Eta square is η^2	Significance of the effect
	66	65	35.571	0.951	Scale of the impact is large

From this table it is clear that the value of the ETA square in these tests is greater than 0.15, which indicates that the size of the program's impact was significant in developing mathematical thinking among members of the research sample.

Discussion and Conclusion

The results of this experimental study led to the following conclusions: There are significant differences between means of pre-and post-tests scores of experimental group on mathematical thinking. There are significant differences between means of post-tests scores of experimental and control groups on mathematical thinking

This means that the program achieved high effectiveness in developing the mathematical thinking skills. This finding is supported by Yousef Abad Algani (2019) who arrived at the conclusion that innovative and modern strategies should be considered in schools because they proved advantageous in teaching mathematics and developing thinking skills. Moreover, the load of mathematics curricula is to be reconsidered, and the priority should be students understanding of mathematics via exploiting various means and employing modern strategies in teaching mathematics. The researcher believes that the method of teaching mathematics plays an important role in developing students' thinking by following a set of working principles and directives and training them to think through the sequence in

the educational material, and implementing activities to develop their thinking and to build a series of programs that will motivate the student and improve his mental abilities.

Therefore, teachers have to encourage students to get high grades by multiple means, to observe their students and to take proper action for any problem, to employ creative teaching methods, to conduct diagnostic and post-treatment exams, to employ worksheets, to encourage students to participate and ask questions, to avoid too much homework, to identify individual differences, to inform students verbally, respect them, and to encourage when they make an effort, and to link mathematics to reality.

The teacher must develop enrichment activities that the student practices with his colleagues, in order to help him develop his mathematical skills. The teacher must link the various mathematical concepts, discuss them, evaluate and test potential solutions, and develop a self-Teaching style. He should also adopt different strategies with different programs and teaching methods, expanding and deepening educational topics through different strategies. The teacher must choose methods related to multiple intelligences among students to take advantage of in developing students The teacher must choose methods related to multiple intelligences among students to take advantage of in developing students' mental abilities and also allow the student to choose the appropriate field in terms of mental superiority, and developing his skills in problem solving and self-learning skills and self-learning. He must always evaluate his teaching programs and develop them in order for the student to develop his thinking skills. The teacher must always choose the appropriate programs and syllabuses based on his qualification, experience and, of course, taking into account the needs of students. That the method of exploration develops the thinking style of students it requires the development of teaching methods and practices, and making students free from traditional education and ritual learning, which requires professional training for teachers.

Recommendations

For further Research

Measuring the effectiveness of a diagnostic remedial program in overcoming mathematics difficulties. Studying mathematics thinking skills in different stages. Specifying the effect of mathematics thinking skills on the other subjects. Studying the relationship between the skills of Arabic language and mathematics skills. The effectiveness of different teaching strategies on improving the study of mathematics.

For Applicants

Increasing the concern of mathematics thinking from the primary stage. Enriching algebra and geometry textbooks with symbolic concepts and expressions, and the ways of reading them to develop mathematical thinking. Textbooks and educational curricula should be developed in line with the skills of the 21st century. In order for the student to master them, they must contain different skills and various methods to increase the student's motivation in studying mathematics and to connect mathematics with reality. Identifying the difficulties in mathematics thinking and the remedial ways of getting over them in different grades. Developing the mathematical thinking skills for the pupils, training the mathematics teachers to build activities and missions that will develop the thinking style of the student, and using different ways to teach mathematics inside and outside the educational session. Developing interaction, dialogue and discussion between students, asking questions that raise their interest and allowing them to exchange views on the educational subject and to discuss ideas, Exploiting student solutions to discuss and understand different methods of solution and common mistakes, Presenting different assessment methods to evaluate students' interaction.

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