Effectiveness of Mathematical Modeling in a Technological Environment and Its Impact on Developing Motivation toward Learning Mathematics among Students in Middle Schools in Israel

Nabil Assadi*, Wafiq Hibi

Department of Mathematics Education, Sakhnin College, Sakhnin, 2173, Israel

Received August 29, 2021; Revised November 13, 2021; Accepted December 13, 2021

Cite This Paper in the following Citation Styles

(a): [1] Nabil Assadi, Wafiq Hibi, "Effectiveness of Mathematical Modeling in a Technological Environment and Its Impact on Developing Motivation toward Learning Mathematics among Students in Middle Schools in Israel," *Universal Journal of Educational Research*, Vol. 10, No. 1, pp. 89 - 102, 2022. DOI: 10.13189/ujer.2022.100109.

(b): Nabil Assadi, Wafiq Hibi (2022). *Effectiveness of Mathematical Modeling in a Technological Environment and Its Impact on Developing Motivation toward Learning Mathematics among Students in Middle Schools in Israel*. *Universal Journal of Educational Research*, 10(1), 89 - 102. DOI: 10.13189/ujer.2022.100109.

Copyright©2022 by authors, all rights reserved. Authors agree that this article remains permanently open access under the terms of the Creative Commons Attribution License 4.0 International License

Abstract The study aims to identify the effectiveness of mathematical modeling in a technological environment, and its effect on the development of middle school learners' critical thinking skills and motivation rising toward mathematics as a subject in Rahat area/ Negev region. In this study, the researcher employed the experimental approach where the two tools of the study were applied to two groups of eighth graders: (group A, control group, 29 learners) and (group B, test group, 30 learners). The tools employed were, first, measuring learners' motivations towards learning, and second, measuring the degree to which learners possess the skills of critical thinking. The tools were used in both the prior and the latter stages of mathematical modeling where a questionnaire was prepared with the aim of identifying the views of students in the middle schools about their motivation to learn mathematics, and the questionnaire included the three dimensions of the study. The second tool consists of a set of questions that measure the degree to which the student has critical thinking skills by answering the test questions (consisting of a set of questions selected to test students in critical thinking skills in solving mathematical problems). The two instruments were initially presented to a group of competent arbitrators in order to benefit from their expertise, and after presenting them and making the necessary adjustments, they were produced in their final

form. The results were as follows: 1. The scale of the student's desire towards learning mathematics, and their sense of perseverance and awareness were all intermediate. 2. Learners' average in the prior test that was designed to measure their skills in critical thinking was low. 3. The study shows variations in the degree of motivation toward mathematics learning regarding their desire and awareness of the importance of the subject. 4. The study shows a variation in the degree of the possession of critical thinking skills in middle school learners. The variation was in favor of the test group.

Keywords Mathematical Modeling, Motivation, Mathematics Education

1. Introduction

Technological advances have made it possible to develop modern and highly-advanced educational systems through harnessing all available tools and resources to create an abundant technological environment which ultimately benefits education in general. It goes without saying that those who work in the prior field will always strive to achieve the most efficient methods to enhance the

learner's educational and behavioral skills. Among these pioneering methods is mathematical modeling.

According to Borromeo (2006), Mathematical modeling is a process in which real-life problems and situations are exemplified by mathematical terms and correlations. The prior is carried out to identify the problems and, later, attempt to solve them. Through mathematical modeling, a real-life problem is simply turned into a mathematical equation.

Hansen (2010) argues that Mathematical modeling is a channel through which a learner could find mathematics easier to learn; mathematical modeling represents mathematical concepts and embodies them physically. It could also enhance cognitive skills and thinking processes. To mathematics learners, mathematical modeling has become a necessity.

According to Mina (2006, 2017) stresses that mathematical modeling is only an active application of mathematics. In mathematical modeling a problem or a situation that occurred in real life is converted in a mathematical problem which is an answer to the real problem. Through the prior, learners can truly appreciate the importance of mathematics in life, and imagine its legion applications that go beyond their school books.

Abu Zaina et al., (2010) argues that the teaching of mathematics needs to be enriched with conceptual processes as learners can achieve the highest grades if they comprehended the procedure with no need for a real understanding of the concept. In the prior, the student will be stranded if a question's form is altered.

Sharbini (2003) suggests that giving attention to the development of the student's awareness of their actual activities within the learning process, and ensuring that it goes along with the modern orientations that stress the fact that a student must reach a degree of awareness regarding his/her educational knowledge will not be necessarily sufficient to achieve an acceptable degree of attainment. They, the students, must be aware that achieving the prior is not possible without being competent in terms of methods and strategies implemented to achieve the level of awareness of what they have learned and acquired.

According to the study of Niu and Horenstein (2011) the teachers' active practice of higher cognitive strategies that target verification and prediction makes it possible for mathematical thinking abilities to thrive. The priors include the search for the truth, openness, self-confidence, and matureness. Our ever-shifting world and life-style require students to be able to make decisions and solve problems. No matter what role they might play in their societies later, they must have the necessary ability to analyze unfamiliar situations.

study was to detect the impact of the use of mathematical modeling on the development of critical thinking skills in 9th grade female students of mathematics. In order to achieve the prior, a study tool was represented in the form of a test of the five skills of critical thinking (defining the hypotheses, interpretation, induction, deduction, and evaluation of evidence and argument). Throughout the study, a semi-experimental approach was implemented. The number of participants in the sample was (74) female students, where two classes were chosen randomly. One class of (38) students was designated as an experimental group, and its counterpart was the control one. The (36) students of the control group studied mathematics for the designated period following the traditional approach of teaching. According to the study results, variations of statistical significance were in favor of the experimental group, with whom, mathematical modeling was actively employed. The study recommended that more attention must be rendered to mathematical modeling as a teaching methodology in the teaching of mathematics.

In the study of (Dawoud, 2018), the researcher aims to exam Efficiency of modeling strategy in developing the oral skills and linguistic self-concept among students in the faculty of sharia. The researcher has prepared a performance test, observational notes for oral skills, a measure of self-concept, and a teacher's guide for using modeling strategy. The sample consisted of (65) students from the college of Sharia and Islamic studies at Al-Qassim university in Saudi Arabia. Findings revealed the effectiveness of modeling strategies in developing the oral skills and the linguistic self-concept in favor of the experimental group over the control group. The study recommended using the modeling strategy in the development of various skills of students at the selected college.

Earlier in 2017, a study was conducted by (Al-Ersan) that aims to identifying the effectiveness of using some active learning strategies in developing the Cognitive flexibility and academic Achievement Motivation. The active learning strategies used in the study were cooperative learning, discussion and dialogue, and brainstorming. The study was conducted on a sample of (65) students of the Faculty of Education at the University of Hail psychology majors, all of whom enrolled in educational psychology course. Participants were randomly selected during the academic year (2014- 2015) and were divided into two groups: the experimental group, consisting of (33) students, and the control group, consisting of (32) students. To achieve the purpose of this study, two scales were used: the Cognitive flexibility scale and academic achievement motivation scale. The validity and reliability of scales were verified in the proper methods. The study results showed that there were statistically significant differences between the average performance of students in the experimental and control groups in cognitive flexibility scale and academic

2. Literature Review

According to Nimrat et al, (2020), the objective of

achievement motivation scale in favor of experimental group attributed to active learning strategies. In light of these findings, the study assigned a number of recommendations including the need to encourage faculty members to employ active learning strategies.

(Asempapa, 2015) argues for the implementation of mathematical modeling activities within the elementary and middle school years in United States. The article also discusses challenges associated with mathematical modeling from both teachers' and students' perspectives. Examples of authentic modeling tasks are illustrated in this article to indicate the relevance and importance of mathematical modeling and it is shown that elementary and middle school students are capable of engaging in such modeling tasks. It is argued that mathematical modeling tasks are powerful vehicles for developing quantitative reasoning, problem-solving skills, and modeling competencies in the early school years. The article demonstrates that mathematical modeling tasks encourage the development of a wide range of mathematical practices and 21st century learning skills that are useful for real-life situations and today's world.

In their study of 2015, (Santos et al.) determined the effects of the integration of mathematical modeling on the problem-solving performance and math anxiety level of Grade 9 students. Two groups of students were exposed to different strategies: the control group was taught using guided practice while the experimental group was taught using the integration of mathematical modeling. Pretests and Posttests were given to measure the performance of both groups in terms of their problem-solving skills and their math anxiety level. T-test of independent and dependent were used to determine whether there exists significant difference between the performance of the two groups in terms of their pretest and posttest scores. Questionnaire and Interview Method were implemented were used to elicit students' reactions on the integration of mathematical modeling in the classroom findings showed that there is a significant difference between the pretest and posttest mean scores of both groups in terms of their problem-solving performance test and their mathematics anxiety test. However, when their posttest mean scores were compared, the experimental group made a large improvement in terms of their problem-solving performance and a reduction in terms of their mathematics anxiety level, thus, the integration of mathematical modeling was effective in improving the problem-solving performance and reducing the math anxiety level of students.

The study of (Wethall, 2011) determined the effects of the integration of mathematical modeling on the problem-solving performance and math anxiety level of Grade 9 students. Two groups of students were exposed to different strategies: the control group was taught using guided practice while the experimental group was taught using the integration of mathematical modeling. Pretests and Posttests were given to measure the performance of

both groups in terms of their problem-solving skills and their math anxiety level. T-test of independent and dependent were used to determine whether there exists a significant difference between the two groups in their pretest and posttest scores. Questionnaire and Interview Method were implemented were used to elicit students' reactions to the integration of mathematical modeling in the classroom. Findings showed that there is a significant difference between the pretest and posttest mean scores of both groups in their problem-solving performance test and their mathematics anxiety test. However, when their posttest mean scores were compared, the experimental group made a large improvement in t their problem-solving performance and a reduction in terms of their mathematics anxiety level, thus, the integration of mathematical modeling was effective in improving the problem-solving performance and reducing the math anxiety level of students.

Critical thinking has important implications for classic learning issues such as transfer of knowledge and application of problem-solving skills to novel situations. The goal of this study was to identify some of the important correlates of critical thinking, in terms of motivation, use of cognitive learning strategies, and classroom experiences. Participants (N=758) were college students attending three Midwestern institutions (a community college; a small private college; and a comprehensive university) during the 1987-88 school year. Twelve classrooms were sampled, spanning three disciplines: biology (three classes, N=219); English (three classes, N=110); and social science (six classes, N=429). The Motivated Strategies for Learning Questionnaires (MSLQ) was administered to students at the beginning and at the end of the winter 1988 school term. The results of the analyses lend further support for the positive relationship between "deep" processing (in this case, critical thinking) and an intrinsic goal orientation. The relationship between critical thinking and a mastery orientation however is tempered by the content domain. Intrinsic goal orientation is a significant, positive predictor of critical thinking for biology and social science students, but not for English students, at both the pretest and posttest. Metacognitive self-regulatory strategies were consistently positively related to critical thinking, both across domains and at the two time points. In summary, this study supported the positive relationship between motivation, deep strategy use, and critical thinking.

3. Problem of the Study

According to Barwel (2003), the massive scientific evolution and the spread of knowledge and creativity are all factors that have made the teaching of mathematics with a variety of methods an absolute necessity. The prior is needed to enable the students to remain up-to-date with

the growth of knowledge and to stay enriched, creative and capable to produce knowledge themselves.

Mohsen (2007) argues that teaching mathematics isn't at all an easy task; it requires numerous demands and procedures, especially because mathematics has a more abstract nature than other subjects. Based on the prior, lack of understanding in one particularity might affect the comprehension of the next.

One of the most outstanding of the priors is mathematical modeling and its overall impact on the educational process. All the priors lead to one major question:

How effective is Mathematical Modeling in a technological environment and its impact on developing Motivation toward Learning Mathematics among Students in Middle Schools in Israel?

4. Objectives of the Study

This study aims to fulfill the following objectives:

1. To identify the real circumstances regarding the teaching of mathematics at middle schools in Rahat area/Negev region.
2. To identify the students' overall attainment in mathematics at middle schools within the designated geographical area.
3. To identify the most prominent methods and pedagogues implanted in the teaching of mathematics within the study community.
4. To measure the level of students' motivation towards learning mathematics at middle schools.
5. To measure the impact of applying mathematical modeling in a technological environment and its correlation with the development of critical thinking skills.

5. Hypotheses of the Study

1. There are no variations with a statistical significance at ($\alpha \leq 0.05$) in the students' motivation towards learning mathematics, sense of perseverance regarding the prior, and acknowledging the importance of mathematics as a subject at middle schools.

2. There is no variation with a statistical significance at ($\alpha \leq 0.05$) regarding the student's possession of critical thinking skills in mathematics at middle schools.

6. Variables of the Study

1. The independent variable: the implement methods by which comparison between mathematical modeling and the classical method of teaching is conducted.
2. Subsidiary variables:

- Critical thinking skills.
- Students' motivation towards learning.

7. Significance of the Study

1. This study is one of very few focusing directly and specifically on the significance of mathematical modeling and its impact on the development of metacognitive skills in a technological environment.
2. It focuses on the indispensable role of mathematical modeling in the educational process.
3. It draws attention to the importance of technological investment in education.
4. It helps inform educators of the ways of implementing mathematical modeling in the educational process.
5. It helps promote the development of critical thinking skills.
6. It helps in finding new viable ways for promoting and reinforcing motivation and genuine desire towards learning.
7. It provides current and future researchers with the methodology of mathematical modeling application.
8. It provides several procedures of mathematical modeling to be used in practice.

8. Boundaries of the Study

- **Timeline:** First semester of the scholastic year (2020/2021)
- **Location:** Middle schools in Rahat area/Negev region-Israel.
- **Objective and academic boundaries:** Analysis and measurement of mathematical modeling and its impact on the development of critical thinking skills in Israel.
- **Human boundaries:** All students at middle schools in Rahat area/Negev region- Israel.

8.1. Study Community

The study community will be made up of all students studying in middle schools in Rahat/Negev region-Israel during the first semester of the 2020/2021 academic year.

8.2. Study Sample

The sample of the study was selected in a cluster edited manner, where:

- (Al-Najah Preparatory School) was randomly selected from about (15) schools in the region.
- It was found that the school includes three classes: 8th, 9th, and 10th, and the eighth grade were randomly selected.

- To achieve the goal, two divisions were selected out of the four divisions in a random manner.
- The control group was randomly selected as well. It contained a total of (30) students.

Table 1 shows the distribution of sample members in the control and experimental groups and by gender variable:

Table 1. Distribution of sample members in the control and experimental groups according to the number of students and by gender variable

Group	Gender	Number	Total
Control	male	10	29
	Female	19	
Experimental	male	12	30
	Female	18	
Total		59	

8.3. Study Tools

In order to achieve the objectives of the study, the study tools were constructed to precisely measure the effectiveness of mathematical modeling in a technological environment, and its effect in the development of critical thinking skills and motivation rising toward mathematics. The researchers resorted to a number of previous studies to help construct the appropriate tools, namely (Nimrat et al, 2020), (Shummari, 2018), (Abu Sara, 2018), (Firdaus et al, 2015), and (Santos et al, 2015). To obtain data from its secondary source, the researcher used two tools for the study as follows.

8.3.1. The first tool (measuring motivation for learning):

A questionnaire was prepared with the aim of identifying

the views of students in the middle schools about their motivation to learn mathematics, and the questionnaire included three dimensions:

- The first dimension: (the desire to learn mathematics) and it consists of (7) paragraphs.
- The second: (feeling of perseverance towards learning mathematics) and it consists of (9) paragraphs.
- The third dimension: (understanding the importance of learning mathematics) and it consists of (7) paragraphs.

8.3.2. The second tool (measuring the degree of possession of critical thinking skills):

It consists of a set of questions that measure the degree to which the student has critical thinking skills by answering the test questions (consisting of a set of questions selected to test students in critical thinking skills in solving mathematical problems.

The two instruments were initially presented to a group of competent arbitrators in order to benefit from their expertise, and after presenting them and making the necessary adjustments, they were produced in their final form.

8.4. Sincerity of the Study Tool

The arbitrators made some observations about them, and accordingly they were presented in their current form. The researcher verified the validity of the questionnaire statistically and calculated the Pearson correlation coefficient (Correlation) for the study paragraphs in each dimension of the study with its overall degree in the field, as described in the following table:

Table 2. The results of the Pearson Correlation coefficient between each of the study paragraphs in each dimension of the resolution with its overall score

Paragraph No.	Paragraph	Coefficient (R)	Statistical significance
The first dimension			
1	I have a desire to adhere to math classes and not to be absent.	0.817**	0.000
2	I love math and I'm glad to learn it.	0.598**	0.000
3	I care more about learning math than other subjects.	0.212	0.107
4	I'm always thinking about math problems.	0.228	0.083
5	I always feel like meditating on solving mathematical issues.	0.465**	0.000
6	I feel a positive energy that attracts me to learning math.	0.722**	0.000
7	I have a great desire to learn math and learn about it.	0.794**	0.000
The second dimension (persistent towards learning mathematics)			
8	I'm trying to get the information, no matter how hard it is to do so.	0.348**	0.007
9	I start discussing and participating during math class.	0.333**	0.010
10	I care about classroom activities and contribute to solving them.	0.697**	0.000
11	I'm looking for the right solutions.	0.438**	0.001
12	I help my colleagues think and discuss solutions.	0.673**	0.000
13	I care about home activities and exercises and try to solve them without delay.	0.740**	0.000
14	I am looking for solutions from the Internet and from its various sources	0.499**	0.000
15	I'm doing everything I can to participate in the workshops.	0.651**	0.000
16	I take the initiative to prepare the educational means requested by the teacher.	0.201	0.126
The third dimension (the importance of learning mathematics)			
17	I think learning math is important and has limitless applications in real-life.	0.660**	0.000
18	I'm trying to learn math for use in my future career.	0.609**	0.000
19	Learning math stimulates memory and activates thinking skills	0.460**	0.000
20	I think mathematics develops human mental abilities.	0.583**	0.000
21	Learning math boosts self-confidence	0.516**	0.000
22	I feel that learning math raises my positive energy levels.	0.762**	0.000
23	I think mathematics has a role to play in all walks of life.	0.578**	0.000

* The relation is statistically significant at the level (0.05)

Table 2 shows that the study tool has a very high degree of statistical sincerity, and that this tool with its components is valid for what was developed to measure.

8.5. The Stability of the Study Tool

The stability of the study tool was verified using the stability equation: (Cronbach's Alpha) for internal consistency, where the value was calculated between the paragraphs in each dimension of the study and among all the paragraphs combined, as shown in the table 3.

It is clear from table 3 that the value of alpha calculated between the paragraphs of the study dealing with the first dimension (to learn mathematics) was (0.672). The alpha value calculated between the paragraphs of the study dealing with the second dimension was (0.663). The alpha value calculated between the paragraphs of the study dealing with the third dimension (the importance of

mathematics) was (0.683). The alpha value calculated between all paragraphs in this area was 88.1%. This means that alpha values were all high. It is clear to us that the study tool has a very high degree of consistency required to be adopted as a tool for achieving the objectives of the study and implementing its procedures.

Table 3. Internal consistency coefficient (Cronbach's Alpha) between the study paragraphs in each dimension of the study and all the paragraphs combined

Dimension	Value of stability factor (Kronbach Alpha)	Number of paragraph
The first dimension	0.672	7
The second dimension	0.663	9
The third dimension	0.683	7
Total degree	0.811	23

8.6. Statistical Treatment

After collecting the data of the study, the researcher reviewed it to prepare for its introduction to the computer, to make statistical processing of the data. The prior was introduced by assigning it certain numbers according to the pentagonal Leckert scale, so that the higher the degree, the higher the importance of the scale and the higher the degree of acceptance and approval, as described in the following table:

Table 4. Conversion of verbal answers into digital answers to be entered into the SPSS

Verbal answer	Always	Often	Sometimes	Rarely	Not at all
Answer in numbers	5	4	3	2	1

The data were statistically processed by extracting numbers, percentages, computational averages, standard deviations, Pearson correlation (t-test, triangular heterogeneity test, one -way ANCOVA, and kronbach's alpha stability equation, using the SPSS statistical packet program.

9. Study Results

● What is the reality of motivating students to learn mathematics in middle schools from the learners' point of view?

To answer the previous question, the researcher drafted three sub-questions addressing the dimensions of this issue and discussed it, as follows:

Question one: What is the degree to which students in middle schools have a tendency towards the first

dimension of the study from the learners' point of view?

In order to answer the previous question, the mathematical averages and standard deviations of the study paragraphs were extracted on the degree of possession of students in the middle schools to wish to learn the mathematical material arranged according to the importance of the most prominent, as described in the following table 5.

Table 5 shows that the response grades of the sample members about the degree of possession of students in the middle schools towards the first dimension ranged from high to medium. The total score was (3.42), which is average according to the study scale, with a standard deviation (0.445).

The previous table shows that the most important things that shows that students in the middle schools towards the first dimension is what is mentioned in paragraph1, which received the highest response, namely (the desire to adhere to math classes and not to be absent), with a mathematical average of (3.83) and a standard deviation of (0.931). This is followed by paragraph (6) which is (feeling the positive energy that attracts the student towards learning mathematics), where the mathematical average (3.71) was a standard deviation of (0.921). This is followed by paragraph 7, which is (the student has a great tendency towards the first dimension where the mathematical average (3.63) was a standard deviation of (0.945). This is followed by paragraph 2, which is (the student's love for mathematics and his eagerness to learn it), where the mathematical average (3.47) was a standard deviation of (0.704). The lowest response ratings among the sample members were on paragraph (4), which is (student thinking permanently in mathematical problems), with a mathematical average (2.64) with a standard deviation of (0.550).

Table 5. Averages and standard deviations of the study paragraphs on the degree of possession of students in middle school desire to learn mathematics ranked according to importance

Order	Number in resolution	Paragraphs	Average	Standard deviation	Class
1	1	I have a desire to adhere to math classes and not to be absent.	3.83	0.931	High
2	6	I feel a positive energy that attracts me to learning math.	3.75	0.921	High
3	7	I have a great desire to learn math and learn about it.	3.63	0.945	High
4	2	I love math and I'm strongly attracted to learn it.	3.47	0.704	Medium
5	5	I always feel like meditating on solving mathematical problems.	3.37	0.554	Medium
6	3	I care more about learning math than other subjects.	3.24	0.625	Medium
7	4	I'm always thinking about math problems.	2.64	0.550	Medium
Total degree			3.42	0.445	Medium

Question two: What is the reality of the feeling of tendency towards the second dimension among students in middle schools from the learners' point of view?

To answer the previous question, the averages and standard deviations of the study paragraphs were extracted on the reality of the feeling of perseverance of tendency towards the second dimension among students in the middle schools arranged according to the importance of the most prominent statement, as described in the following table 6.

According to table 6, majority of the response grades of the sample members about the reality of the feeling of perseverance towards learning mathematics among students in the middle schools were high. The total score was (3.23), which is average according to the study scale, with a standard deviation (0.437).

Table 6 shows that the most important and most prominent features of the feeling of perseverance towards learning mathematics among students in the middle school area is what is mentioned in paragraph 13, which is (the student's interest in activities and home training and trying to solve them without delay), with an average account (4.10) and a standard deviation of (0.931). This is

followed by paragraph 15, which is (the student did everything he could to participate in the workshops), where the average (3.93) was a standard deviation of (0.876). This is followed by paragraph 12, which is (helping the student to his colleagues to think and discuss solutions), where the average (3.88) was a standard deviation of (0.892). This is followed by paragraph 10, which is (the student's interest in classroom activities and his contribution to solving them), where the average (3.78) was a standard deviation of (0.918). The lowest response rate among the sample members was on paragraph 8 (student's quest for information no matter how difficult it was to reach it), with a mathematical average of (1.62) with a standard deviation of (0.721).

- **How important is it to learn mathematics from the learners' point of view?**

To answer the previous question, the averages and standard deviations of the study paragraphs were extracted on the extent to which students in the middle are aware of the importance of learning mathematics arranged according to the importance of the most prominent statement, as described in the following table 7.

Table 6. Averages and standard deviations of the study paragraphs on the reality of the tendency towards the second dimension among students in middle schools ranked by importance

Order	Number in resolution	Paragraphs	Average	Standard deviation	Class
1	13	I care about home activities and exercises and try to solve them without delay.	4.10	0.831	High
2	15	I'm doing everything I can to participate in the workshops.	3.93	0.876	High
3	12	I help my colleagues think and discuss solutions.	3.88	0.892	High
4	10	I care about classroom activities and contribute to solving them.	3.78	0.918	High
5	14	I am looking for solutions from the Internet and from its various sources	3.71	0.948	High
6	11	I'm looking for the right solutions.	3.39	0.831	High
7	16	I take the initiative to prepare the educational means requested by the teacher	2.51	0.774	High
8	9	I start discussing and participating during math class	2.14	0.798	Low
9	8	I'm trying to get the information, no matter how hard it is to get it.	1.62	0.721	Low
Total degree			3.23	0.437	Medium

Table 7. Averages and standard deviations of the study paragraphs on the third dimension of the study

Order	Number in resolution	Paragraphs	Average	Standard deviation	Class
1	17	I think learning math is important and its applications in life.	3.83	0.968	High
2	18	I'm trying to learn math for use in my career.	3.51	0.989	High
3	23	I think mathematics has a role to play in all walks of life.	3.05	0.879	Medium
4	19	Learning math stimulates memory and activates thinking skills	2.50	0.600	Low
5	20	I think mathematics develops human mental abilities.	2.41	0.726	Low
6	22	I feel like learning math raises my positive energy level.	2.32	0.730	Low
7	21	Learning math boosts self-confidence	2.02	0.601	Low
Total degree			2.81	0.478	Medium

It is clear from table 7 that the response grades of the sample members on the third dimension of the study ranged from high to low. The total score was (2.81), which is average according to the study scale, with a standard deviation of (0.478).

The previous table shows that the most important and prominent indicators of the awareness of students in the middle schools of the importance of learning mathematics is what is mentioned in paragraph 17, which is (the student believes that learning mathematics is important and it has limitless applications in real-life), with an average of (3.83) and a standard deviation of (0.968). This is followed by paragraph 18, which is (the student's quest to learn mathematics in order to use it in his profession), where the mathematical average (3.51) was a standard deviation of (0.989). This is followed by the paragraph 23, which is (the student's belief that mathematics has its role in all the different aspects of life), where the mathematical average (3.05) was a standard deviation of (0.879). This is followed by the statement in paragraph 19: "Learning mathematics stimulates memory and activates thinking skills," where the average (2.50) was a standard deviation of (0.600). Paragraph 21 had the lowest response rate among the sample members, which is that "learning mathematics enhances self-confidence," with a mathematical average of (2.02) with a standard deviation of (0.601).

Question three: How high are critical thinking skills in mathematics of the students at schools from the learners' point of view?

To answer the previous question, the mathematical averages and standard deviations of the students' scores in the test were extracted critical thinking skills (pretest), as described in the following table 8.

Table 8 clearly demonstrates that the average numeracy

of students in the traditional test designed to measure critical thinking skills has reached (14.03) which is low according to the test scale and its great end is (40), which shows that students in middle schools lack the critical thinking skills they need in learning mathematics.

Table 8. Averages and standard deviations of students' scores in the test critical thinking skills (traditional method of teaching)

Scale	The Great End	Average	Standard deviation	Class
The degree to which students possess critical thinking skills in mathematics	40	14.03	3.957	Low

● How equal is the motivation to learn mathematics between the sample members in the experimental and control groups (before conducting mathematical modeling)?

To answer the previous question, the researcher used a T-test for differences in the reality of motivation to learn mathematics (before conducting mathematical modeling) between the experimental and control groups, as shown in the following table 9.

According to table 9, the value of the statistical indication corresponding to the study measure on all the dimensions of the study in addition to the overall degree of motivation towards mathematics learning was: (0.739), (0.814), (0.974), (0.977) respectively. All of them are larger than (0.05), and this result means that there are no statistically significant differences at the level ($\alpha \leq 0.05$) in the three dimensions of the study in addition to the overall degree of motivation between the averages of the driving measures of learning (pretest) in the control and experimental groups. This indicates that the motivation to learn mathematics in its dimensions in the control and experimental groups was equal before conducting mathematical modeling.

Table 9. T-test results for differences in the reality of motivation to learn mathematics (before conducting mathematical modeling) between the experimental and control groups

Scale	Group	Number	Average	Standard deviation	Calculated T value	Degrees of freedom	Statistical significance
The degree to which you have tendency towards the first dimension	Control	29	3.399	0.434	-0.335	57	0.739
	Experimental	30	3.438	0.461			
The level of tendency towards the second dimension	Control	29	3.241	0.401	0.236	57	0.814
	Experimental	30	3.214	0.475			
The level of tendency towards the third dimension	Control	29	2.812	0.595	0.032	57	0.974
	Experimental	30	2.808	0.339			
Total degree	Control	29	3.151	0.342	-0.028	57	0.977
	Experimental	30	3.153	0.376			

- **How equal is the degree of possession of students in middle schools for critical thinking skills in mathematics between the sample members of the experimental and control groups (before conducting mathematical modeling)?**

To answer the previous question, the researcher used the T-test to find the differences in the degree of possession of students in the middle schools for critical thinking skills in mathematics between the members of the sample in the experimental and control groups (before conducting mathematical modeling), as shown in the table 10.

- **Does the degree of motivation of students to learn in their dimensions are aware of the different teaching method (mathematical modeling in a technological environment, or the traditional method)?**

To answer the previous question, the researcher formulated the following hypothesis in preparation for testing and discussing:

Theorem 1

There are no statistically significant differences at the level of significance ($\alpha \leq 0.05$) in the degree of motivation to learn mathematics in its dimensions is recognized among students in the middle schools due to the teaching method.

To verify the validity of the hypothesis, the averages and deviations of the standard deviations of motivation altogether to learn mathematics are recognized in the two stages-(Traditional and dimensional) among students in the middle schools in the control and experimental groups, as shown in the table 11.

The data in table 11 shows that there are virtual differences between the mathematical averages of the three dimensions of the study and the overall degree between the control and experimental groups after applying the mathematical modeling method to the experimental group. To verify the substance of these differences, the (One Way ANCOVA test) was used for the three dimensions of the study and the overall score between the control and experimental groups, as shown in the table 12.

Table 10. Results of the T-test for differences in the degree of possession of students in middle schools in the for critical thinking skills in mathematics between the members of the sample in the experimental and control groups (before conducting mathematical modeling)

Scale	Group	Number	Average	Standard deviation	Calculated T value	Degrees of freedom	Statistical significance
Degree of critical thinking skills in mathematics	Control	29	14.310	3.072	0.562	57	0.577
	Experimental	30	13.767	4.248			

Table 11. Averages and standardized deviations of motivation altogether to learn mathematics in its dimensions and total degree in the two stages- (pretest and posttest) among students in middle schools in the control and experimental groups

Stage	Group	Statistical measure	The degree to which you have the tendency towards dimension no.1	The degree to which you have the tendency towards dimension no.2	The degree to which you have the tendency towards dimension no.3	College degree
Pretest	Control	Average	3.399	3.241	2.812	3.151
		Standard deviation	0.434	0.401	0.595	0.342
	Experimental	Average	3.438	3.214	2.808	3.153
		Standard deviation	0.461	0.475	0.339	0.376
posttest	Control	Average	3.468	3.375	2.901	3.248
		Standard deviation	0.704	0.518	0.425	0.376
	Experimental	Average	3.848	3.879	4.015	3.914
		Standard deviation	0.479	0.586	0.640	0.526

Table 12. One Way ANCOVA test for motivational scores to learn mathematics in its dimensions and total score between the control and experimental groups

Source of variance	Domain	Total squares	Degrees of freedom	Average squares	Calculated P value	Level of statistical significance
Pretest	1 st dimension	0.413	1	0.413	1.150	0.288
	2 nd dimension	0.122	1	0.122	0.392	0.534
	3 rd dimension	0.000	1	0.000	0.000	0.997
	Total degree	0.103	1	0.103	0.483	0.490
Teaching method	1 st dimension	2.214	1	2.214	6.161	0.016
	2 nd dimension	3.712	1	3.712	11.980	0.001
	3 rd dimension	18.286	1	18.286	60.485	0.000
	Total degree	6.540	1	6.540	30.823	0.000
The error	3 rd dimension	20.124	56	0.359		
	2 nd dimension	17.354	56	0.310		
	3 rd dimension	16.930	56	0.302		
	Total degree	11.882	56	0.212		
correction	3 rd dimension	22.671	58			
	2 nd dimension	21.234	58			
	3 rd dimension	35.216	58			
	Total degree	18.531	58			

Table 12 clearly states that there are differences at the level of significance $\alpha \leq 0.05$ in the degree of motivation to learn mathematics in terms of the study's three dimensions and generally among students in middle schools. The calculated (P) value in the dimensional measurement according to the teaching method in order (6.161), (11.980), (60.485), and (30.823) and in terms of Statistics (0.016), (0.001), (0.000), (0.000), all less than (0.05), and according to table number (11), we find that the differences were in favor of the experimental group. In all cases, this indicates an effect to deal with the effectiveness of mathematical modeling in the development of motivational degree to learn mathematics in terms of the three main dimensions of the study and generally in students in middle schools.

● **Does the degree of critical thinking skills in mathematics vary according to the teaching method (mathematical modeling in a technological environment, or the traditional method)?**

To answer the previous question, the researcher formulated the following hypothesis in preparation for testing and discussing:

Theorem 2

There are no statistically significant differences at the level of significance ($\alpha \leq 0.05$) in the degree of possessing critical thinking skills in mathematics among students in middle schools due to the teaching method.

To verify the validity of the hypothesis, the averages and standard deviations of the degrees of critical thinking skills in mathematics in the two stages- (pretest and posttest) were calculated among students in the middle schools in the control and experimental groups, as shown in the following table:

Table 13. Averages and standard deviations of grades of critical thinking skills in mathematics in the two stages- (pretest and posttest) among students in middle in the control and experimental groups

Group	Statistical measure	Pretest	Dimension
Control	Average	14.310	22.069
	Standard deviation	3.685	6.094
Experimental	Average	13.767	24.900
	Standard deviation	4.248	7.779

In accordance with table 13, there are virtual differences between the mathematical averages of the degrees of critical thinking skills in mathematics in the two stages- (pretest and posttest) among students in the middle schools in the control and experimental groups between the control and experimental groups, after applying the method of mathematical modeling to the experimental group. To verify the substance of these differences, the (One Way ANCOVA test) was used for the degrees of critical thinking skills in mathematics in the two phases- (pretest and posttest) among students in the middle schools in the control and experimental groups as shown in the following table 14.

Table 14. One Way ANCOVA test for critical thinking skills scores in mathematics between the control and experimental groups

Scale	Source of variance	Total squares	Degrees of freedom	Average squares	F	Level of statistical significance
Degrees of critical thinking skills in mathematics	pretest	2077.255	1	2077.255	268.718	0.000
	Teaching method	194.837	1	194.837	25.205	0.000
	The error	432.893	56	7.730		
	Correction	2622.644	58			

According to table 14, differences at the level of significance ($\alpha \leq 0.05$) in the degrees of possessing critical thinking skills in mathematics among students in the middle schools, where the value of (F) in the distance measurement according to the method of teaching (25.205) and statistical lyceum (0.000) which is less than (0.05), and referring to table 13, we find that the differences were in favor of the experimental group, which indicates an effect to deal with the effectiveness of mathematical modeling in the development of critical thinking skills in mathematics skills in students in the middle.

10. Conclusions

The researcher explains this result that the desire to learn mathematics was moderate as a result of the lack of appropriate methods to teach it. Various sources of distraction became a concern for many members of the society. The prior influences come along with the nature of the subject of mathematics, which needs will, determination and higher thinking skills.

The results indicated that the overall degree of response to the study's second dimension among students in the middle reached its total score of (3.23) which is average, with a standard deviation of (0.437).

The results also showed that the most important and highlighted features of the second dimension of the study among students in the middle schools is (the student's interest in activities and home training sought to solve them without delay), (the student did everything he can to participate in the workshops), and (help his colleagues to think and discuss solutions). In addition, (the student's interest in classroom activities and his contribution to their solution).

This result was not entirely consistent with the results of the Abu Qayas study (2017), which showed that estimates of the trend towards effort in mathematics learning were high.

The researcher attributes this result to the fact that perseverance comes from the availability of desire, and that the lack of availability of stimuli contributed to the decline of interest and led to a lack of interest in learning mathematics in general. The prior could also result in the loss of the sense of perseverance among students and their

motivation to participate in workshops.

It turns out that the most important and most prominent indicators of the awareness of students in the middle of the importance of learning mathematics is (the student's belief that learning mathematics is important and it has limitless applications in real-life), and (the student's quest to learn mathematics in order to use it in his profession later on), as well as (the student's belief that mathematics has a role in all aspects of life), finally, (learning mathematics stimulates memory and activates thinking skills).

This result was not entirely consistent with the results of the (Abu Qayas study (2017) which showed that estimates of the importance or value of mathematics and the trend towards teacher and mathematics were high.

The researcher believes that the student's awareness of the importance of learning mathematics is one of the main pillars that must be taken into account in the teaching of mathematics, especially since mathematics has its many applications in life, and intervenes in the majority of fields. And, therefore educating students about the importance of learning mathematics has become one of the most important goals to be achieved before starting the process itself.

The results showed that the average achievement of students in the pretest designed to measure critical thinking skills reached (14.03) from its great end (40), which is low according to the test scale. The prior indicates that students in middle schools Region lack the critical thinking skills they need in learning mathematics.

It is also noticeable that there are no statistically significant differences at the level ($\alpha \leq 0.05$) in the degree of possession of students in the middle schools in for critical thinking skills in mathematics between the members of the sample in the experimental and control groups (prior to the conduct of mathematical modeling). This indicates that students in middle schools in had critical thinking skills in mathematics in the control and experimental groups were equal before conducting mathematical modeling.

The researcher explains the prior finding by stating that students in the control and experimental groups are no different from each other in the degree of their critical thinking skills in mathematics, which achieves the conditions for using the curriculum. The prior requires the equality of the control and experimental groups in the

field of study before conducting any test.

There are no statistically significant differences at the level of significance ($\alpha \leq 0.05$) in the degree of motivation to learn mathematics in its dimensions is recognized among students in the middle schools due to the teaching method.

The results showed that there were significant differences at the level of significance ($\alpha \leq 0.05$) in the degrees of possessing critical thinking skills in mathematics among students in middle schools. The results also showed that the differences were in favor of the experimental group, indicating the effectiveness of mathematical modeling in the development of critical thinking skills in mathematics students.

The results of the current study were in agreement with the results of the study (Nimrat et al., 2020), the study of (Abdulrahim, 2018), the study of (Touba, 2014), the study of (Al-Jahni, 2013), and the study of (Wahyuddin and Syahri, 2018), and finally the study of (Firdaus et al, 2015), which showed a significant impact and a strong correlation between the use of different strategies, particularly modeling strategies, and the development of critical thinking skills in mathematics learning.

The researcher explains the previous result by stating that learning mathematics requires a set of special skills to support the understanding and perception of the individuals, and to enable them to follow the most appropriate ways to assimilate the content. Perhaps, the skills of critical thinking are among of the most prominent skills needed by the individual to overcome many outstanding issues in mathematics, and in order to develop and strengthen those skills, the individual must resort to the use of educational strategies that commensurate with the educational position, and that the strategy of mathematical modeling is one of the most appropriate and most important strategies necessary to develop critical thinking skills.

11. Recommendations

In light of previous findings, the researcher came up with a set of recommendations, some of which are:

- The need to start preparing the necessary educational strategies to stimulate students' motivation towards learning.
- Working on the development of educational methods and methods used in teaching mathematics in accordance with the subject of the study.
- Working on training courses to prepare teachers who are able to employ learning strategies, particularly modeling strategies in educational activities.
- The need to activate the role of technology in lessons, and home activities.
- Working to develop critical thinking skills among students to ensure that they understand what they are learning.
- The need to provide all the necessary possibilities for motivates students and raise the level of motivation to learn.
- The need to tackle at the reasons behind the low educational achievement of students in mathematics in particular, and working on developing appropriate solutions to ensure that their achievement level is raised.
- The need to provide a suitable technological environment that facilitates the application of different educational strategies.
- Working on further research and studies that are concerned with the issue of mathematical modeling and its impact on the motivation to learn on the one hand and in the development of critical thinking skills on the other.

REFERENCES

- [1] Abdulrahim, D., "The impact of the use of modeling strategy on the achievement of geometric thinking among middle-grade students," Unpublished master's thesis, Al-Mustansiriyah University - Faculty of Basic Education - Department of Teaching Methods, Baghdad, 2018.
- [2] Abu Qayas, Y., "Students' attitudes and motivation towards learning mathematics and their self-concept and feelings while learning it at the higher basic level in the Directorate of Qabatiya," unpublished master's thesis, An-Najah National University Press, Nablus, 2017.
- [3] Abu Zaina, F., Ababana, A., "Mathematics curricula for the first grade," Ministry of education and Higher Education. Ramallah, 2007.
- [4] Al-Ersan, S., "The effectiveness of using active learning strategies based on social cognitive theory in the development of cognitive flexibility and motivational academic achievement in the student of the Department of Psychology at Hail University," Journal of The Open University of Jerusalem for Research and Educational and Psychological Studies - Volume(5), Issue(18), (159-177), 2017.
- [5] Al-Jahni, F., "The use of educational games and its effect the acquisition of critical thinking skills in the mathematics course of middle-grade students in Mecca," Unpublished master's thesis, department of curriculum and teaching methods, Faculty of Education, Um al-Qura University, Saudi Arabia, 2013.
- [6] Al-Sharbini, H., "The relationship between beyond-knowledge skills and the achievement goals and the method of attributing failure among university students," Journal of Studies in Education. 2003
- [7] Asempapa, R., "Mathematical Modeling: Essential for Elementary and Middle School Students, Ohio University, Athens, Ohio, USA," Journal of Mathematics Education, 8 (1), pp. (16-29), 2015.

- [8] Barwel, R., "Patterns of attention in the interaction of a primary school mathematics student with English as an additional language," *Educational Studies in Mathematics*, vol. 53, pp. (35–59), 2003
- [9] Behar-Horenstein, L. S., & Niu, L., "Teaching Critical Thinking Skills In Higher Education: A Review Of The Literature," *Journal of College Teaching and Learning* 8(2), pp. (25-42), 2011.
- [10] Borromeo, R. Ferri., "Theoretical and empirical differentiations of phases in the modeling process," *Berlin*, 38 (2) 86, 2006.
- [11] Dawoud, S., " The effectiveness of the strategy of the development of the skills of rhetoric and the concept of linguistic self among students of the Faculty of Sharia, Department of Advocacy and Culture, University of Al-Qasim- Faculty of Sharia and Islamic Studies," *Journal of Educational and Psychological Sciences*, Volume(18),Issue(4),(265-302), 2018
- [12] Firdaus, F., Kailani, I., Bakar, M. N. B., & Bakry, B., "Developing critical thinking skills of students in mathematics learning," *Journal of Education and Learning*, 9(3), 226-236, 2020
- [13] Hansen, A., "Instructional Responsibility in Mathematics Education: Modelling Classroom Teaching Using Swedish Data," *Educ. Stud. Math.* 75, 171-189. 2010
- [14] Larsen, Y., Bogner, F., Buchholz, H., & Brosda, C., "Evaluation of A Portable and Interactive Augmented Reality Learning System by Teachers and Students, open classroom conference augmented reality in education, Ellinogermaniki Agogi, Athens, Greece, October., 2011, pp. 41-50.
- [15] Mina, F., "Issues in mathematics education and learning," i (1), *Anglo-Egyptian Library*, Cairo, 2006.
- [16] Mohsen, A., "Educational opinions in learning mathematics," *Damascus*, 2007.
- [17] Santos, M., Rosemarievic, V., Rene, R., "Mathematical modeling: effects on problem-solving performance and math anxiety of students," *International Letters of Social and Humanistic Sciences Online*, Vol. 65, pp. (103-115), 2015.
- [18] Touba, R., "Impact of mathematical modeling strategy on understanding concepts and resolving mathematical problems among seventh-grade students in the measurement unit," *Unpublished master's thesis*, An-Najah National University Press, Nablus, 2014.
- [19] Wahyuddin, A., "Implementation of Learning Problem Solving in Improving Critical Thinking Ability in Mathematics Students, *IOSR Journal of Mathematics*," 14 (3), pp. (06-11), 2018.
- [20] Wethall, N., "The Impact of Mathematical Modeling on Student Learning and Attitudes." *The Evergreen State College Press*, 2011.