*Research Article*

# The Status of Mathematics Education in Terms of Mathematical Modeling to Solve Real World Problems by Thai Teachers and the Science and Mathematics Program of Twelfth Grade Students

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## ABTRACT

The purpose of this study is to investigate the status of mathematics education in terms of mathematical modeling for problem solving in real-life situations among teachers and students of science and mathematics program in twelfth grade. The sample group included 92 twelfth grade science-mathematics program students selected by stratified random sampling. And 10 mathematics teachers were selected through purposive sampling. The research instruments include; (1) The questionnaire on beliefs about mathematical modeling, (2) The test of students' ability to engage in mathematical modeling. (3) The interview questionnaire on teaching and learning for teachers. The statistics used in the study include mean, standard deviation and correlation coefficient. The results of the study are: (1) students and teachers have high levels of beliefs regarding mathematical modeling, (2) the relationship of beliefs for each question among students was found that the highest positive the Pearson correlation value is 0.65, (3) the relationship of beliefs for each question among teachers was found that the highest positive the Pearson correlation value is 1.0, (4) Students lack experience in mathematical modeling of real-world problems, so they were unable to construct a mathematical model to solve a real-world problem. The results of this research will guide teachers and researchers in the design and development of teaching and learning activities that improve students' mathematical modeling skills.

**Keywords** Mathematics instruction, Mathematical modeling, Beliefs regarding mathematical modeling

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## Introduction

Mathematics plays a crucial role in 21st century learning success because it enables individuals to think creatively, logically, systematically and analytically. It helps to make predictions, plan, make decisions and solve problems accurately and appropriately. In addition, math is an indispensable tool for studying various fields such as science, technology and other subjects [1]. When solving real-world problems, mathematics is often used to understand and explain reality, taking into account both the mathematical answers and their logical consequences in the real world [2]. This is consistent with Chamberlin's [3] statement that real-world problems, especially those that are difficult and complex, often require mathematical reasoning to represent reality. Applying mathematics to problem solving leads to precise, principled answers and helps to overcome challenges and obstacles in the real world. Even with these complex problems [4], people can use mathematical models to find solutions.

In previous math classes, students had knowledge and understanding of the content, but some still had difficulty applying math knowledge to problem solving or reasoning. This problem prevented students from using their mathematical knowledge effectively in real-life situations. This is in line with Isariya's [5] observation that although students learn to solve mathematical problems, the problems they encounter are often confined to the classroom, some of which are not relevant to their real lives. As a result, students lack real-life examples of problems, which limits their ability to apply mathematical knowledge to their own lives. This suggests that teachers lack experience in incorporating diverse mathematical knowledge into activities aimed at developing mathematical modeling skills to solve real-world problem for students. This includes some teachers who have a limited understanding of mathematical models and are unable to organize classroom activities and design activities that promote students' mathematical modeling skills. They also believe that mathematical models are distant and irrelevant to students. Therefore, it is critical to focus on examining teachers' and students' beliefs about mathematical modeling and students' ability to construct mathematical models to solve real-world problems in twelfth-grade science and mathematics classrooms. This is because the nation's expectations for the core basic education curriculum are that students in this program will become important assets to the country upon completion of their basic education, able to apply their mathematical knowledge to solve real-world problems [6].

For all of the above reasons, the researchers question what the current state of mathematics education should be in terms of mathematical modeling to solve real world problems for twelfth grade students in the Science-Math program. Furthermore, this information will serve as a guide for the development of future instructional activities that will enhance students' ability to mathematically model to solve real world problems.

## Literature Review

### Mathematical Model and Mathematical Modeling

*Mathematical models* have been defined by many educators. The researcher summarized these definitions [6-12] and concluded that they mean: A mathematical model is something that is created based on mathematical concepts. It is used to understand and explain the properties of various phenomena or situations that occur in real life in mathematical form. It allows the representation of phenomena or situations in mathematical form, such as functions, graphs, tables, equations and inequalities, which can be adapted and flexibly designed according to the context of the study. On the other hand, *mathematical modeling* is a dynamic process that involves different methods and steps, depending on the application or the approaches developed by educators. For this study, the researcher summarized the processes [6-12] and concluded that mathematical modeling is the process of systematically examining real-life situations by understanding or explaining them in mathematical terms. Various conditions are then adjusted to simplify the process of finding solutions. Relevant mathematical knowledge is used, variables are defined, and mathematical models are constructed. These models are used to find solutions for real-life situations. Finally, the answers are interpreted back into the real context, or the models created are further adapted for similar situations.

The difference between a mathematical model and mathematical modeling [12] is that a mathematical model is simply a mathematical concept that has been created, such as the equation $y = ax+b$. Mathematical modeling, on the other hand, is the process that leads to the construction of a mathematical model.

The importance of constructing mathematical models, which has been studied by researchers among students and mathematicians, lies not only in their importance for classroom management, but also in their application in real-life scenarios. Building mathematical models stimulates students' interest in mathematics and promotes the connection between the real world and the mathematical world. Learning to construct mathematical models contributes to the development of analytical thinking, logical reasoning, problem-solving skills and the ability to integrate mathematical models with various other disciplines. Furthermore, given the numerous complex problems in the real world, it is essential to construct mathematical models to explain and understand them. If the mathematical models created are accurate enough, they can be further developed into predictive models that help anticipate future events and develop strategies to overcome the various challenges that may arise. [6-12]

The advantages of mathematical models [6-12] are that they can help to mathematically explain various real-world problems that people face. They use mathematical knowledge and principles to solve these problems and obtain answers. For example, in problems such as choosing the best savings account to maximize returns, factors such as principal, interest, time period and the bank's terms and conditions must be considered. Similarly, choosing the best promotional offer for a product may require evaluating the quantity of the product, length of use and guarantee terms. In agribusiness, selecting the best crop type for maximum yield might involve evaluating growth rates, fertilizer use and cost conditions. In addition, the importance of mathematical models is widely recognized in fields such as physics, chemistry, biology, economics and industry to gain deep insights into the diverse nature of the world. Mathematical models help solve problems by providing appropriate solutions tailored to different contexts.

**Beliefs regarding mathematical modeling to solve real-world problems**

The researcher investigated and synthesized beliefs in the context of mathematical modeling of Isariya [5], Taschapone [13], Jeerasak [14] and Janjaruporn [15] and concluded that beliefs are the acceptance of something as true based on direct experience, analytical reasoning or inference that influences feelings, thoughts and utterances.

Teachers' beliefs about mathematical modeling refer to the acceptance of certain aspects of mathematics, mathematical modeling, and teaching as true based on teachers' experiences and perspectives.

Students' beliefs about mathematical modeling refer to the acceptance of certain aspects of mathematics, mathematical modeling, and learning as true based on students' experiences and perspectives.

Divided into 3 aspects: (1) beliefs related to mathematics, (2) beliefs related to mathematical modeling, and (3) beliefs related to teaching and learning through mathematical modeling, the results of the synthesis are presented in Table 1.

**Table 1** Beliefs regarding mathematical modeling

| **Beliefs regarding mathematics** | |
|---|---|
| **No.** | **Considerations** |
| 1 | Results in mathematics can be flexible and change depending on the method. |
| 2 | Mathematics is a subject concerned with numerical operations. |
| 3 | Results in mathematics are always precise, exact and constant. |
| 4 | Mathematics is a subject with fixed knowledge that cannot be recreated |
| 5 | Mathematics is a subject that promotes students' logical thinking, systematic thinking and analytical skills. |
| 6 | Memorizing formulas, performing the specified steps, and performing calculations are the most important aspects in mathematics. |
| 7 | Mathematics is a content that can be applied in solving problems and making decisions in everyday life. |
| 8 | Mathematics is a complex subject that requires memorization of formulas and is therefore difficult to understand. |
| 9 | New knowledge in mathematics is constantly emerging. |
| 10 | Mathematics is a subject that involves memorizing formulas, carrying out the given steps and performing calculations. |
| **Beliefs regarding mathematical modeling** | |
| **No.** | **Considerations** |
| 11 | We can solve problems in real-life situations in various ways. |

| | |
|---|---|
| 12 | We can solve problems using mathematical modeling (such as formulas, equations, tables, graphs, functions) without necessarily considering the process of creating the mathematical model. |
| 13 | Using a process to represent or explain a real-life situation in the form of a mathematical problem and selecting mathematical knowledge can help in solving real-life situations. |
| 14 | The outcome of mathematical modeling is uncertain, but it is beneficial to problem solving because the results are certain and widely applicable if one accepts the inherent limitations that come with it. We accept the inherent limitations that come with it. |
| 15 | When constructing mathematical models (such as formulas, equations, tables, graphs, functions) to solve problems, these can be developed or modified from existing models. |
| 16 | When solving mathematical problems, constructing mathematical models (such as formulas, equations, tables, graphs, and functions) helps to find precise answers or solutions. |
| 17 | The specification and goals of constructing mathematical models (such as formulas, equations, tables, graphs, and functions) vary according to assumptions, variables, methods and interpretations. |
| 18 | When solving mathematical problems, it is important to construct mathematical models based on existing formulas, functions or various equations. For example, linear equations, quadratic equations and others. |
| 19 | The results obtained in the construction of mathematical models (such as formulas, equations, tables, graphs and functions) should be checked for accuracy both in the mathematical context and in the real world. |
| 20 | In solving real-world problems, we may not be able to construct mathematical models to assist in solving every problem. |
| **Beliefs regarding instruction through mathematical modeling** | |
| **No.** | **Considerations** |
| 21 | In learning management for problem solving, the mathematical problem scenarios used should ideally be familiar to the students. |
| 22 | In each teaching activity, teachers should provide an overall assessment when evaluating students' mathematical processes at each step. |
| 23 | To foster continuous learning, teachers should organize group activities and use probing questions to encourage students to think progressively. |
| 24 | In organizing mathematical modeling activities, teachers can choose any real-life situation and provide it to students for constructing mathematical models to solve real-world problems. |
| 25 | Teaching methods that encourage students to explain their reasoning and then look for relationships within the given data to help them develop the ability to construct mathematical models. |

| | |
|---|---|
| 26 | Assessment of students' ability to construct mathematical models must include specific and targeted questions that are aligned with the process of mathematical modeling. |
| 27 | Performance measurement tests are an important tool for assessing students' ability to construct mathematical models. |
| 28 | Teaching students to simply search for answers helps students build mathematical models. |
| 29 | In organizing mathematical modeling activities, teachers should choose real- world situations that facilitate the use of mathematical modeling processes to solve problems. |
| 30 | Organizing teaching and learning activities that focus on having students find answers alone will cause students to learn. |

**Definition of terms**

1. The status of mathematics education in relation to mathematical modeling to solve real world problems are 1) Beliefs regarding mathematical modeling to solve real world problems of students and teachers. 2) Students' ability in mathematical modeling to solve real world problems.

2. Beliefs regarding mathematical modeling for solving real-world problems is the acceptance of something related to mathematical modeling as truth based on direct experience, analytical reasoning, or inference and includes three dimensions: (1) Beliefs regarding mathematics, (2) Beliefs regarding mathematical modeling, (3) Beliefs regarding teaching and learning through mathematical modeling.

3. Beliefs regarding mathematical modeling to solve real world problems of teachers is the acceptance of something in mathematics, mathematical modeling and teaching through mathematical modeling as truth, based on the experiences and perspectives of teachers.

4. Beliefs regarding mathematical modeling to solve real world problems of students is the acceptance of something in mathematics, mathematical modeling and teaching through mathematical modeling as truth, based on the experiences and perspectives of students.

5. Students' mathematical modeling ability to solve real-world problems is the result of the test of students' mathematical modeling ability and their written answers.

6. School refers to Bangkapi School, Secondary Education Service Area Office, Bangkok Metropolitan Administration, District 2.

7. The students refer to the twelfth-grade students, Science-Math program, at Bangkapi School. There are 3 classrooms with 40 students each. Each classroom consists of high, medium and low achieving students.

8. Teacher refers to the math teachers at Bangkapi School who have at least 2 years of teaching experience.

**Research methodology**

This study uses a quantitative research approach to analyze teachers' and students' beliefs and students' abilities to construct mathematical models, and a qualitative research approach to analyze teachers' and students' deep-seated beliefs and the quality of students' written responses. In addition, this investigation includes a literature review and relevant theoretical frameworks regarding mathematical modeling, beliefs regarding mathematical modeling, and mathematical modeling ability. The review includes a discussion, summary and substantiation of the findings and recommendations for further research [16-18].

**Research objectives**

Investigating the status of mathematics education in relation to mathematical modeling for problem solving in real-world problems among twelfth grade science-math program teachers and students.

**Research conceptual framework**

The study examines the state of mathematics education in relation to mathematical modeling. The researchers designed (1) a questionnaire on beliefs about mathematical modeling for students and teachers using the Fennema-Sherman framework [19], (2) a test of students' ability to engage in mathematical modeling using the framework developed by Niss, Blum & Galbraith [20], and (3) an interview questionnaire on teaching and learning for teachers using the framework proposed by Janjaruporn [15].

**Conflict of interest statement**

This study was reviewed and approved by the institutional ethics committee of Srinakharinwirot University (SWUEC672169). The authors declare that there is no conflict of interest.

**Population and sample**

The population for this study consisted of 120 twelfth grade students in the science-math program at Bangkapi School, District Office of Secondary Education Area 2, Bangkok. The sample group consisted of 92 twelfth grade students in the science and mathematics program in the second semester of academic year 2566 (B.E.). The participants were selected by stratified random sampling based on their grades in basic math subjects. They were divided into three groups: High achievers (30 students), Medium achievers (60 students) and Low achievers (30 students). A simple random sample was then drawn within each group so that 23 students were selected from the high-achieving group, 46 students from the medium-achieving group and 23 students from the low-achieving group. The sample size was determined using the Yamane formula [21] with a sampling error of 0.5. In addition, 10 mathematics teachers from Bangkapi School were selected through purposive sampling.

**Data collection tools**

Data collection from students are (1) a questionnaire on beliefs about mathematical modeling, and (2) a test of students' ability to engage in mathematical modeling. These instruments were used to collect data from the target group of students.

Data collection from teachers are (1) a questionnaire on beliefs about mathematical modeling, and (2) an interview questionnaire on teaching and learning for teachers. These instruments were used to collect data from the target group of teachers

The questionnaire assesses beliefs in three dimensions as follows: (1) beliefs regarding mathematics, (2) beliefs regarding mathematical modeling, and (3) beliefs regarding instruction through mathematical modeling. Each dimension comprises 10 questions, making a total of 30 questions. The rating scale consists of four levels: high, high, low and lowest. The questionnaire, interview and test were validated by experts, with an IOC score of +1.00 for each question, and all questions were objective.

The test of students' ability to engage in mathematical modeling was reviewed by experts for content validity, with an IOC score of +1.00. The test also ensured objectivity, with the difficulty index (p) ranging from 0.2 to 0.8 and the discrimination index (r) starting at 0.4 for all questions.

The interview questionnaire on teaching and learning for teachers was reviewed by experts for content validity, achieving an IOC score of +1.00 and ensuring objectivity of all questions.

**Statistics used in data analysis**

**Analyzing student data**

(1) In analyzing the questionnaire on beliefs about mathematical modeling for students, the researchers used basic statistics such as mean and standard deviation and analyzed the Pearson correlation coefficient for each question. The data on beliefs were interpreted using the criteria and conceptual framework of Fennema-Sherman [19].

(2) In analyzing the test of students' ability to engage in mathematical modeling, the researchers employed qualitative data analysis methods, specifically multiple analysis triangulati on, analytic induction, and scoring using a rubric. The data were interpreted using the framework of Niss, Blum & Galbraith [20].

**Analyzing teacher data**

(1) In analyzing the questionnaire on beliefs about mathematical modeling for teachers, the researchers used basic statistics such as mean and standard deviation and analyzed the Pearson correlation coefficient for each question. The data on beliefs were interpreted using the criteria and conceptual framework of Fennema-Sherman [19].

(2) In analyzing an interview questionnaire on teaching and learning for teachers, the researchers used qualitative data analysis methods, specifically multiple analysis triangulation and analytic induction. The data were interpreted using Janjaruporn's framework [15].

**Collection of information**

To gather the necessary information, the researchers obtained permission from Bangkapi School to inquire about teachers' and students' beliefs and to assess students' ability to construct mathematical models. This took place from April 5 to April 30, 2024, and the researchers supervised the participating students in completing the data collection and checking the accuracy of the data. The data was then coded and processed using appropriate computer programs to enable analysis, synthesis and summarization of the results.

## Research Result

**1.1 Beliefs regarding mathematical modeling to solve real-world problems held by students and teachers.**

The researchers analyzed students' and teachers' beliefs about mathematical modeling to solve real-world problems using the data in the questionnaire on students' and teachers' beliefs about mathematical modeling to solve real-world problems. The results of the analysis are presented in Table 2. (Due to the detail of the means and correlations for all questionnaire items, please contact the corresponding author for further information)

**Table 2** Beliefs regarding mathematical modeling to solve real-world problems of students and teachers.

| Beliefs | Students | | | Teachers | | |
|---|---|---|---|---|---|---|
| | Mean | S.D. | Scale | Mean | S.D. | Scale |
| Beliefs regarding mathematics | 3.13 | 0.83 | high | 2.88 | 0.69 | high |
| Beliefs regarding mathematical modeling | 3.26 | 0.71 | high | 3.03 | 0.63 | high |
| Beliefs regarding instruction through mathematical modeling | 3.24 | 0.73 | high | 2.89 | 0.74 | high |

The results of the analysis are as follows:

**1. Beliefs regarding mathematical modeling to solve real-world problems of students.**

Students have a high level of beliefs regarding mathematical modeling to solve real world problems. When looking at the individual belief statements, it was found that the belief with the lowest mean score is the belief that "mathematics is a subject with fixed knowledge that cannot be recreated", with a mean score of 2.35 and a standard deviation of 1.22. This belief relates to the aspect of mathematics.

**2. Beliefs regarding mathematical modeling to solve real-world problems of teachers.**

Teachers have high levels of beliefs about mathematical modeling to solve real world problems. When looking at the individual belief statements, it was found that the belief with the lowest mean score is the belief that "mathematics is a subject with fixed knowledge that cannot be recreated", with a mean score of 1.50 and a standard deviation of 0.71. This belief relates to the aspect of mathematics.

**3. The relationship between beliefs regarding mathematical modeling to solve real-world problems of students.**

When looking at the relationships for each question, the three most positive correlations are as follows:

(1) When solving mathematical problems, constructing mathematical models (such as formulas, equations, tables, graphs, and functions) helps to find precise answers or solutions. When solving mathematical problems, it is important to construct mathematical models based on existing formulas, functions or various equations. For example, linear equations, quadratic equations and others. Pearson's correlation coefficient is 0.65.

(2) Mathematics is a content that can be applied in solving problems and making decisions in everyday life. The outcome of mathematical modeling is uncertain, but it is beneficial to problem solving because the results are certain and widely applicable if one accepts the inherent limitations that come with it. We accept the inherent limitations that come with it. Pearson's correlation coefficient is 0.61.

(3) Mathematics is a content that can be applied in solving problems and making decisions in everyday life. Using a process to represent or explain a real-life situation in the form of a mathematical problem and selecting mathematical knowledge can help in solving real-life situations. Pearson's correlation coefficient is 0.59.

One the other hand, the three most important negative correlations are the following:

(1) Memorizing formulas, performing the specified steps, and performing calculations are the most important aspects in mathematics. The specification and goals of constructing mathematical models (such as formulas, equations, tables, graphs, and functions) vary according to assumptions, variables, methods and interpretations. The Pearson correlation coefficient is -0.34.

(2) Results in mathematics can be flexible and change depending on the method. Mathematics is a complex subject that requires memorization of formulas and is therefore difficult to understand. The Pearson correlation coefficient is -0.32.

(3) Mathematics is a subject that promotes students' logical thinking, systematic thinking and analytical skills. Mathematics is a subject that involves memorizing formulas, carrying out the given steps and performing calculations. The Pearson correlation coefficient is -0.31.

**4. The relationship between regarding mathematical modeling to solve real-world problems of teachers.**

When looking at the relationships for each question, the three most positive correlations are as follows:

(1) The outcome of mathematical modeling is uncertain, but it is beneficial to problem solving because the results are certain and widely applicable if one accepts the inherent limitations that come with it. We accept the inherent limitations that come with it. In learning management for problem

solving, the mathematical problem scenarios used should ideally be familiar to the students. The Pearson correlation coefficient is 1.0.

(2) When constructing mathematical models (such as formulas, equations, tables, graphs, functions) to solve problems, these can be developed or modified from existing models. Assessment of students' ability to construct mathematical models must include specific and targeted questions that are aligned with the process of mathematical modeling. The Pearson correlation coefficient is 1.0.

(3) Memorizing formulas, performing the specified steps, and performing calculations are the most important aspects in mathematics. In solving real-world problems, we may not be able to construct mathematical models to solve every problem. Pearson's correlation coefficient is 0.94.

One the other hand, the three most important negative correlations are the following:

(1) Mathematics is a subject with fixed knowledge that cannot be recreated. Teaching methods that encourage students to explain their reasoning and then look for relationships within the given data to help them develop the ability to construct mathematical models. The Pearson correlation coefficient is -0.75.

(2) Results in mathematics are always precise, exact and constant. When solving mathematical problems, it is important to construct mathematical models based on existing formulas, functions or various equations. For example, linear equations, quadratic equations and others. Pearson's correlation coefficient is -0.73.

(3) The results obtained in the construction of mathematical models (such as formulas, equations, tables, graphs and functions) should be checked for accuracy both in the mathematical context and in the real world. Performance measurement tests are an important tool for assessing students' ability to construct mathematical models. The Pearson correlation coefficient is -0.69.

**5. Students' mathematical modeling ability to solve real-world problems**

The researchers analyzed students' mathematical modeling ability to solve real-world problems using various writing samples and interviews with a selected target group of students. The results of the analysis are as follows:

5.1 Understanding a real-world problem

The analysis revealed that the majority of students do not prioritize the understanding of real-world problem. The students' behaviors show four characteristics: (1) Reading the real- world problem and questions with very little time. (2) Not emphasizing important texts, both in the conditions and in the questions of the real- world problem. (3) No search for additional information from other sources. (4) No creation of tables to compare important data or different conditions.

5.2 Simplification

The analysis showed that the students' behavior had two characteristics: (1) Not specifying the knowledge used to search for answers. (2) No specification of additional details leading to the search for answers.

5.3 Define mathematical model

The analysis revealed that the students' behavior has three characteristics: (1) No explanation of the concepts used to search for answers. (2) No conversion of important data or conditions of the real-world problem into mathematical symbols. (3) The majority of students are unable to solve real-world problems through mathematical modeling.

5.4 Using mathematics

The analysis revealed that students' behavior has two characteristics: (1) No demonstration of the method of finding answers through mathematical models to solve real-world problems. (2) No comparison or verification of answers to real-world problems.

5.5 Explain results

The analysis showed that the students' behavior had two characteristics: (1) No explanation of how the answers received could be traced back to the real-world problems. (2) No search for other real-world problems that could be answered with similar approaches.

## Results and Discussion

**Beliefs regarding mathematical modeling to solve real-world problems of students and teachers.**

**1. Beliefs regarding mathematical modeling to solve real-world problems of students**

From Table 2, when carefully considered that the belief with the lowest mean value "Mathematics is a subject with fixed knowledge that cannot be recreated" is a negative belief with the lowest mean value. This belief could be due to the fact that students recognize that new knowledge can be created in mathematics, e.g. through theoretical mathematical projects or the integration of mathematics into daily life. Although students acknowledge in informal conversations that mathematics should be applied in daily life, they may not see clearly how it can be used. However, they believe that it contributes to the creation of new things, which is consistent with the teacher's information that the school encourages students to do math projects every school year. This encourages students to believe that they can always generate new knowledge from math. This aligns with the research findings of Eric L. Mann [22] on creativity in mathematics, who found that students who apply mathematics to their daily lives and engage in creative thinking are able to gain new knowledge from mathematics.

**2. Beliefs regarding mathematical modeling to solve real-world problems of teachers**

From Table 2, when carefully considered that the belief with the lowest mean score is that "Mathematics is a subject with fixed knowledge that cannot be recreated", a negative belief with the lowest mean score. This belief could be due to the teachers' view that various mathematical formulas can always be recreated, even if they are based on pre-existing knowledge. These formulas are seen as new knowledge that is evolving. This is consistent with the teachers' information that Bangkapi School has introduced math project tasks for students every year. Teachers have to do extra research to guide students in creating new formulas. This contributes to teachers holding this belief and aligns with Eric L. Mann's [22] research on creativity: the essence of mathematics, which stated that mathematics is knowledge that does not stagnate. If the users of mathematics are creative, new knowledge will always emerge.

**3. The relationship between beliefs regarding mathematical modeling to solve real-world problems of students.**

From Table 2, when carefully considered that the relationship with the highest positive correlation coefficient is “When solving mathematical problems, constructing mathematical models (such as formulas, equations, tables, graphs, functions) helps to find precise answers or solutions.” and “When solving mathematical problems, it is important to construct mathematical models based on existing formulas, functions or various equations. For example, linear equations, quadratic equations and others.” Students believe that if equations or formulas already exist, they can plug data or values into those formulas to find accurate answers. This belief is consistent with informal information indicating that in regular classroom situations where formulas can be used to substitute values to find answers, students often get correct answers. Both beliefs are therefore positively correlated. This is consistent with Giordano's [23] categorization of mathematical models into four types, where creating formulas or equations belongs to one type of mathematical model that students can use to find answers to problem situations.

**4. The relationship between beliefs regarding mathematical modeling to solve real-world problems of teachers.**

From Table 2, when carefully considered that the relationship with the highest positive correlation coefficient is “The outcome of mathematical modeling is uncertain, but it is beneficial to problem solving because the results are certain and widely applicable if one accepts the inherent limitations that come with it.” and “We accept the inherent limitations that come with it. In learning management for problem solving, the mathematical problem scenarios used should ideally be familiar to the students.” This belief may stem from the view of many teachers that mathematical models can be multifaceted in their usefulness but must be appropriately tailored to the situation at hand. In schools, for example, students are often encouraged to work on math projects each school year, with teachers guiding them to explore new formulas. This leads students to believe that mathematical models are versatile tools that can produce accurate results if used correctly. This belief aligns with the findings of Catherine Muthuri [24], who describes mathematical models as mathematically structured frameworks that can serve different purposes depending on constraints. They can support decision making, predict future events and evolve over time. Ayla Arseven [25] also emphasized that mathematical models bridge different aspects of human life that are directly or indirectly related to mathematics and serve as tools for problem solving and understanding different situations. They allow humans to experiment with solutions to problems before translating them into reality by drawing on mathematical knowledge to overcome real-world challenges. Mathematical models can evolve based on different human experiences.

However, students' and teachers' beliefs about mathematical modeling are contextually limited. It may be necessary to extend the investigation of these beliefs in future studies by including a larger sample of students and teachers.

**The students' mathematical modeling ability to solve real-world problems**

1. Understanding a real-world problem. Most students do not value understanding real-world problem because they read the scenarios and questions very quickly, do not underline or highlight important parts of the conditions and questions, do not seek additional information from research sources, and do not create tables to compare important data or conditions. This could be due to students relying on their previous experiences and not attaching importance to the data, which prevents them from fully understanding real-world problem. This is in line with the study by Isariya [5] who investigated the learning environment for mathematical modeling in lower secondary school. She found that most students do not prioritize understanding real-world problems as they spend very little time reading the real-world problems and do not underline or highlight text, indicating a lack of effort to understand the problems.

2. Simplifying. Most students do not indicate what knowledge they use to find the answers and do not provide additional details that lead to finding the answers. This could be because students do not recognize the need to exclude irrelevant data, resulting in a mixture of useful and irrelevant information. This makes it difficult for students to simplify real- world problem. This is in line with the study by Jeerasak [14], who investigated the learning environment related to solving real-life problems through mathematical modeling for students. It was found that students have difficulty articulating or explaining the process of finding connections or relationships between elements in real-life problems. This makes it difficult for them to use relevant information or conditions to explain the connections or relationships required in real-life problems.

3. Define mathematical model. Most students do not explain their thought processes when searching for answers, nor do they adapt key data or conditions from real-world problems or represent them in mathematical symbols. Furthermore, the majority of students are unable to construct mathematical models to solve real-world problems. This could be because students have difficulty understanding the real-world problem and do not exclude irrelevant data. As a result, the data contains both necessary and unnecessary components for finding solutions, which makes it difficult for students to formulate mathematical models. This is in line with the study by Isariya [5] who investigated the teaching and learning environment for mathematical modeling in lower secondary school. The study found that most students do not convert or represent the key data or conditions of real-world problems into mathematical symbols and that they cannot create or construct appropriate mathematical models for real-world problems. This could be because students do not prioritize understanding real-world problems before attempting to solve them. This leads to them not recognizing the relationships or connections between key data or conditions and the problems being solved. As a result, they are unable to create mathematical models that are appropriate for real-world problems or are unable to construct them.

4. Using mathematics. Most students do not show how to use mathematical models to find answers to real-world problems, and they do not compare or check the answers with real-world problems. This could also be because students are not able to create mathematical models, which prevents them from using the created mathematical models to find solutions. This is consistent with the study by Taschapone [13], which investigated the teaching and learning environment related to the use of mathematical models to solve real-world problems, specifically the use of calculus for students in advanced science courses in high school. The study found that most students are unable to select appropriate mathematical models for mathematical problems, are unable to write descriptions of the process of using mathematical models to find answers to mathematical problems and are unable to recognize the origin of mathematical models. In addition, students do not show how they find answers to mathematical problems.

5. Explaining results. Most students do not explain their answers from the solutions they receive back to the real-world problems, and they do not look for other real-world problems that could be solved in a similar way. It could be that students are unable to find answers because they have not created or are unable to create mathematical models, which hinders their ability to explain the answers. This aligns with the study by Taschapone [13], which examined the teaching and learning environment related to the use of mathematical models to solve real-world problems, specifically the use of calculus for students in advanced science subjects at the high school level. The study found that most students do not write explanations to check the correctness and logical consistency of answers to math problems. They also do not provide descriptions or explanations of answers to real-world problems.

Indeed, the ability to construct mathematical models to solve real-world problems may have contextual limitations for students. Extending the research to a wider range of students could provide a more comprehensive understanding of the challenges and limitations they face in constructing mathematical models. This broader perspective could lead to more effective strategies for improving students' ability to construct mathematical models to solve real-world problems.

## New knowledge from research

From the investigation, analysis, and synthesis of the beliefs regarding mathematical modeling to solve real world problems of students and teachers, the ability to mathematically model to solve real world problems of students, and the depth data from the interviews with teachers and students, the researcher comes to the following conclusions: The study on the status of mathematics education in terms of mathematical modeling to solve real world problems that the researcher identified three main aspects, namely; (1) curriculum, (2) teachers, (3) students and the analysis results are detailed as follows:

### 1. Curriculum

The mathematics curriculum according to the Basic Education Core Curriculum B.E. 2551 (revised edition B.E. 2560) was analyzed through interviews with teachers. The majority of teachers stated that the curriculum focuses more on content. The time allocated for teaching does not match the reality as it is impossible to cover the content within the allocated time frame. This is due to other extracurricular activities that take place outside the classroom, so students do not have enough time to complete the curriculum. Furthermore, the extensive content of the curriculum forces students to rush through lessons in order to cover the required material in the allotted time, as exams or competitions, whether in schools or college entrance exams, only cover the content mentioned in the curriculum. Consequently, there is not enough time to organize activities to promote or develop students' mathematical skills. In addition, the curriculum provides few guidelines for organizing skill-building activities, which makes it difficult for teachers to promote students' development. The curriculum structure provided by educational institutions also hinders these efforts. This could be related to the institution's policy of aiming for higher grades of students without focusing on developing their skills and processes.

**2. Teacher**

**2.1 Knowledge of mathematical modeling**

Many teachers have a limited understanding of mathematical modeling. They believe that mathematical models (such as formulas, equations, tables, graphs, functions) can be used to solve problems without considering the steps/processes involved in constructing mathematical models. This may be because teachers rely on their previous experiences to construct mathematical models, which leads them to not clearly understand that what they are creating is actually a mathematical model. However, most teachers agree that math can be used to solve real-world problems and that the results they create, such as formulas, equations, tables, graphs, and functions, can be used in a variety of ways.

There are different opinions among teachers about the need to construct mathematical models to solve various real-world problems. Some teachers believe that a mathematical model must be constructed for all problems, typically in the form of formulas, equations, and functions, while others believe that not all problems require mathematical modeling and that solutions can be adapted to the particular context of the problem. They argue that mathematical modeling should be flexible and adaptable to different situations. Some problems may be solved more efficiently by drawing on past experience rather than constructing mathematical models.

**2.2 Instruction regarding mathematical modeling**

Most teachers generally believe that when selecting problem-solving situations, math problem situations or real- world problem, those that are familiar to the students should be used. The reason for this is so that students can recognize the connection between the world of mathematics and the real world. Regarding the selection of real-life situations for teaching, some teachers believe that they should be selected based on the students' abilities, while others believe that any problem can be used. Both groups of teachers agree that the difficulty level of the problem situations should vary, and most teachers believe that teaching students to explain their reasoning and find relationships between given data helps them to improve their ability to construct mathematical models. In addition, teachers agree that students should not only search for answers, but also learn to understand different processes that lead to finding solutions. However, there are different opinions among teachers about the most effective way to assess students' skills in constructing mathematical models. Some believe that performance assessments are the most important tool for assessing students' skills, as they provide a clear measure of student performance. On the other hand, some teachers believe that assessment should include classroom activities and take into account students' performance in these activities. They argue that the exclusive use of performance assessments does not allow for comprehensive assessment and suggest using observations, interviews or additional documents as assessment tools.

**3. Student**

Most students have a poor understanding of the meaning of mathematical models and mathematical modeling, which leads them to be unsure when creating or using mathematical models. Students have limited experience in applying mathematical knowledge to solve real- world problem. Some students do not recognize the importance or relevance of mathematics in real life or everyday life, resulting in a lack of motivation to learn mathematics.

## Conclusion and Recommendation

The purpose of this study is to investigate the status of mathematics education in terms of mathematical modeling for problem solving in real-world problems among teachers and students of science and mathematics program in twelfth grade. The sample group included 92 twelfth grade science-mathematics program students in the second semester of academic year 2566 (B.E.) selected by stratified random sampling. 10 mathematics teachers of Bangkapi School were selected through purposive sampling. The research instruments include; (1) The questionnaire on beliefs about mathematical modeling, (2) The test of students' ability to engage in mathematical modeling. (3) The interview questionnaire on teaching and learning for teachers. The statistics used in the study include mean, standard deviation and correlation coefficient. The results of the study are: (1) students and teachers have high levels of beliefs regarding mathematical modeling. When examining the individual beliefs of students and teachers, it was found that both groups have the lowest mean scores for the belief that “mathematics is a subject with fixed knowledge that cannot be recreated.” (2) the relationship of beliefs for each question among students was found that the highest positive correlation value is associated with the belief that “when solving mathematical problems, constructing mathematical models (such as formulas, equations, tables, graphs, functions) helps to find precise answers or solutions.” and “when solving mathematical problems, it is important to construct mathematical models based on existing formulas, functions or various equations. For example, linear equations, quadratic equations and others.” The Pearson correlation coefficient is 0.65. However, the most negatively correlated belief with a coefficient of -0.34 is “memorizing formulas, performing the specified steps, and performing calculations are the most important aspects in mathematics.” and “the specification and goals of constructing mathematical models (such as formulas, equations, tables, graphs, functions) vary according to assumptions, variables, methods and interpretations.” (3) the relationship of beliefs for each question among teachers was found that the highest positive correlation value is associated with the belief that "The outcome of mathematical modeling is uncertain, but it is beneficial to problem solving because the results are certain and widely applicable if one accepts the inherent limitations that come with it" and "We accept the inherent limitations that come with it. In learning management for problem solving, the mathematical problem scenarios used should ideally be familiar to the students." The Pearson correlation coefficient is 1.0. However, the most negatively correlated belief with a coefficient of -0.75 is "Mathematics is a subject with fixed knowledge that cannot be recreated." and "Teaching methods that encourage students to explain their reasoning and then look for relationships within the given data help them develop the ability to construct mathematical models." (4) Students' ability to mathematical modeling solves real-world problems lack experience because their failure to recognize the importance of understanding the real-world problem before attempting to construct mathematical models. This results in their inability to adapt the real-world problems to facilitate the search for answers, which in turn results in their inability to develop mathematical models that are appropriate for the real-world problem. They are also unable to translate the meaning of the answers obtained from the mathematical models into solutions for real-world problems and extend the scope of the mathematical models. The results of this research will guide teachers and researchers in the design and development of teaching and learning activities that improve students' mathematical modeling skills.

## Suggestion

**Based on the results of the research, the researcher made the following suggestions:**

(1) When using research findings, the context and characteristics of students in their own school should be considered, as this research focuses on examining the beliefs and abilities of twelfth grade students in the integrated science-math curriculum. If these findings are to be applied to other grade levels, it is important to consider the context in terms of students' prior knowledge and experiences.

(2) Activities aimed at improving students' ability to construct mathematical models to solve real-world problems should include a variety of instructional approaches, such as problem-solving instructional methods, inquiry-based instructional methods, and problem-based instructional methods.

**Suggestions for the next research**

(1) Collect data on teaching in other schools in Bangkok and other provinces to consider the overall national context and design a curriculum that meets general or specific needs, or possibly offer it as an elective in secondary school.

(2) Continue to find the beliefs associated with the construction of mathematical models.

(3) Develop and create classroom activities that enhance students' ability to use mathematical modeling to solve real-world problems.

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